# A REVIEW

# LOCAL AUTHORITY OFF SITE EMERGENCY PLANNING

# FOR UK

# NUCLEAR POWER PLANTS

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# LOCAL AUTHORITY OFF SITE EMERGENCY PLANNING IN THE LOCALITY OF UK NUCLEAR POWER PLANTS

## SUMMARY

This Review considers the requirements of *The Radiation (Emergency Preparedness and Public Information) Regulations* (REPPIR) for the local authority to provide off-site emergency plans in response to all reasonably foreseeable radioactive release incidents from nuclear plants – these regulations are now in force and require the local authorities to provide adequate off-site emergency plans in contingency for specific and all reasonably foreseeable accidents and incidents that could result in the release of radioactivity and the declaration of a radiation emergency.

Two radiation incidents are nominated to determine the demands that would be placed on the off-site emergency plans and how the local authorities would cope with a radioactive release incident. The types of radiological incident considered are not full scale releases, being relatively moderate in terms of the total amount of radioactivity available for dispersion and deposition in public areas. These are based i) on an incident involving an irradiated fuel train moving intensely radioactive fuel from a power station to Sellafield, possibly occurring in a densely populated urban area and ii) a release from an operational nuclear reactor (power station) which requires rapid prophylactic countermeasures to thwart the health impact of radio-iodine uptake. Although the transportation of irradiated fuel is specifically exempted from REPPIR, if such an incident did occur then, no doubt, any existing local authority off-site emergency plan would be enacted.

Each of the release scenarios is framed to be just beyond what the nuclear industry considers to be foreseeable and credible accidents, which it determines largely by probabilistic forecasting. This is done for several reasons: First, the tragic events of 11 September introduced the real possibility of future intentional attacks against hazardous plants, so much so that the nuclear safety case has now to give cognisance to intelligently planned incursions rather than resist accidental and mostly random challenges – other than to detect and prevent such acts at the planning stage, there is little that can be done to reduce the vulnerability of nuclear power plants to terrorist attack. Second, the off-site plan must be sufficiently resourceful to respond to and cope with the unexpected since planning only for the entirely expected would be somewhat meaningless if, that is, the nuclear industry would have us believe that only relatively insignificant radioactive releases can occur at UK nuclear power plants. Third and coupled with the release severity is the capability of the off-site plan to extend beyond the immediate locality of the nuclear plant.Inreal terms, this means extending from the detailed emergency planning zone (DEPZ) of one to three kilometres, out to tens of kilometres.

The Review gives particular regard to the ability of the local authority off-site emergency plan to manage the first and immediate phase of the incident release. This phase is assumed to occupy the 24 hours following the commencement of the release because, first, it is a realistic assumption that the majority of members of the public would somehow self-evacuate once they learnt of a nearby incident involving radioactivity and, second, that after a day or so national resources would be brought to bear to deal with the subsequent interim and longer term impacts of the release. Countermeasures in the immediate aftermath of the release incident are particularly important to minimise the internal uptake of radioactive matter and hence limit the ongoing exposure from internally deposited radio-emitters.

It is shown that airborne radioactivity from relatively moderate releases could spread from the incident site necessitating evacuation and sheltering of members of the public well beyond the areas covered by the pre-planned countermeasure zones required of the local authorities. These pre-planned countermeasure zones extent between 1 to 3.3 km from the nuclear power station, depending on the particular power station and, generally, the local authorities reckon that these zones are capable of *'extendibility'* out to 10 km. However, modelling of the atmospheric dispersion and deposition of these radioactive release scenarios show that the land area for which short term countermeasures would be required to extend goes well beyond 10 km, reaching out to 100 km and more.

So considering just the short-term (first 24 hour) requirements of the local authority off-site emergency plans: With the real possibility of a fire engulfment incident involving irradiated fuel in transit, either as a result of accidental circumstances or from a deliberate act of sabotage or terrorist attack, if the radioactive release occurred in an urban environment (ie London or another major city/conurbation), then it might be that upwards of 600,000 members of the public would be advised to shelter and 20,000 to 30,000 might require evacuation. Similar numbers of the public could be involved in an incident centred in a nuclear power station if prevailing winds and weather conditions swept the radioactive plume into a nearby urban centre, for example a radioactive release from Hartlepool power station engulfing the nearby town of Hartlepool.

Presently, local authorities administering the off-site emergency plan adopt central government guidelines for triggering specific countermeasures and for controlling radiation dose to members of the public and local authority employees.

Countermeasures are triggered by specific levels of dose exposure, the so-called Emergency Reference Levels (ERLs), which themselves are based upon a concept of *'acceptability of risk'*. There are a number of reasons why the *'acceptability'* basis of the ERLs will need revision or, indeed, replacement with an entirely different rationale. This is particularly because the events of 11 September were pre-planned intentional and intelligent acts, whereas the existing risk composite adopted by the nuclear industry and government agencies in setting the ERLs is based on a probabilistic reasoning that radiological incidents primarily arise from accidental, unintentional and entirely unintelligent circumstances. Put another way, the ERLs are set at elevated levels on the assumption that the public will accept a higher dose exposure on the basis that the chance of an <u>accidental</u> release is low, but introducing terrorist acts into this *acceptable risk v tolerable consequences* composite invalidates the chance aspect because such acts are not accidental and cannot be forecast from a probabilistic standpoint.

A second reason relates to improving knowledge of the stochastic effects of radiation dose uptake, particularly of radio-iodine in the thyroid. These two reasons have resulted in increasing pressure to lower both the lower and higher ERL thresholds, and for the iodine ERLs, for example, there are current recommendations in place to lower both the higher and lower ERL limits – once ratified these new ERLs could result in prophylactic countermeasures being required for many more thousands of members of the public residing or working in the stable iodine prophylactic countermeasure region of nuclear power plants.

The Review also considers the disparities that are likely to arise between the existing radiation dose regimes adopted by the emergency services (fire brigades, police and ambulance/para medics), local authority employees who will be required to practicably administer the off-site emergency plan, and the guidelines issued by the Health & Safety Executive. Such is the significance of these disparities that practicable implementation of any effective off-site emergency plan may not be possible.

A number of conclusions are drawn:

1) Even though the requirement to have such plans ready draws near for many local authorities, to date very few finalised plans have been placed in the public domain, members of the public and local interest groups do not seem to have been directly consulted (with the local authority preferring, so it seems, to consult with the members of the local nuclear plants Liaison Committee), and we can find no record of any of the prepared plans being rehearsed with members of the public. Moreover, even though there are clear statutory duties on the plant operators, carriers and local authorities to have effective and proven plans in place, there is a sense that these parties are still 'feeling their way' and not at a stage of each having definitive on- and off-site emergency plans in place.

2) The local authorities are, generally, ill-equipped to properly evaluate what could be a very dynamic radiological situation developing in the immediate aftermath of a nuclear incident at a nuclear power plant or that involving nuclear materials in transit. The assumption that the operator would and could immediately and continue to provide radiological advice assumes that in the height of an incident the operator has sufficient human and communications resource to do this and, equally important, the local authority personnel are able to understand and act upon what is likely to be highly specialised information. It may be that the immediate aftermath of a radioactive release incident would be so demanding as to completely occupy all of the operator's on site human resources with the local authority being left very much to its own devices – in these circumstances the local authority may not be able to manage the first few hours of the incident when in the absence of countermeasures consequences to the public could be unacceptably high.

3) Even in the event of a relatively moderate radioactive release, the human resource levels required to effectively manage (mitigate) the consequences to potentially very large numbers of members of the public may not be available to local authorities, nor would the local authority have sufficient time to muster and organise the necessary resources and skills to deal with the immediate aftermath of a radiological incident. Unless adequate levels of information could be transmitted to and understood by members of the public, massive levels of self-evacuation (perhaps not all of which would be absolutely necessary on health protection grounds) could be triggered, generating such a level of ensuing chaos that the local authority actions might be completely disrupted and the off-site emergency plan rendered wholly ineffective.

4) In fact, during the course of a recent full scale exercise at a nuclear power station with a simulated radioiodine release the inability of the emergency response arrangements were shown to be woefully inadequate in several important respects: Amongst the shortcomings of what was, essentially, a table top exercise, at notification of the incident there was no information provided on the type of incident, wind direction, wind speed, etc.. When the messaging systems was established, some confusion arose as to which nuclear power station was actually involved in the incident, with one message being interpreted to mean that the incident was at Sizewell and not, as it was supposed to be, at Bradwell. The system advising on countermeasure implementation was not clear as to whether a particular countermeasure was being advised for implementation or if it had actually been implemented and, to make matters worse, the messaging was displayed in white on the computer VDUs so that when printed it produced blank sheets of paper even though the decision to implement iodate prophylactic countermeasures was taken one hour following the declaration of a radiation emergency. Most significantly, access to the potassium iodate tablets for public distribution was not available until almost eight hours from the start of the release, by which time a considerable thyroid uptake of radioiodine should be assumed to have occurred.

5) There is considerable ambiguity over the level of radiation dose exposure to be agreed with local authority employees and, separately, the emergency services (fire, ambulance and police). To practicably implement the off-site emergency plan the local authority would need many employees and volunteers on the ground in monitoring, surveying, organising and public information roles, yet none of the local authorities approached for this Review had acquired or planned to acquire sufficient levels of protective and monitoring equipment, including personal (real time) dosimetry; the public services unions had not been consulted over agreeing a 'block' radiological management regime for employees; and of the emergency services only the fire brigades had a previously agreed structured radiation dose regime for the any single incident dose, whereas the ambulance association had a zero-tolerance and the police forces (so far as our enquiries were able to ascertain) had nothing in place whatsoever.

6) REPPIR gives no specific regard to acts of sabotage and terrorism which, obviously, are intentional and intelligent attacks on the system as opposed to accidental events which occur, in the main, by chance. Not only should terrorist attacks be considered to be a certainty, and thus should not be dismissed on the basis of probability alone, but the intelligent nature of the attack would be expected to seek out weaknesses and undefended parts of the nuclear system that may not be at risk from accidental circumstances, natural hazards and situations planned for in the military role. In other words, not only might a terrorist attack might result in an incident and aftermath scenario that had not been previously identified and for which no contingency had been laid, but the attack itself might deliberately seek to impede the effectiveness of the off-site emergency plan.

7) In effect, the local authority off-site emergency plans are geared to respond to incidents of manageable dimensions because these are those reasonably foreseeable by the operator. The safety rationale of the nuclear industry is that all reasonably foreseeable incidents (of acceptable frequency of occurrence) must not result in intolerable consequences – this is the basis of the regulatory framework imposed upon the nuclear operators by the Health and Safety Executive. Put another way, the operator is now very unlikely to admit after years of claiming that its nuclear power plants are safe, that it is possible for such plants to suffer damage that would result in intolerable consequences and for which very comprehensive off-site emergency arrangements are required.

8) If terrorism is taken into account there is a clear dichotomy in emergency planning at local and national levels: At the local level the REPPIR off-site plans cater for relatively small scale and 'manageable' incidents and give no specific regard to acts of terrorism, other than to claim that the plans can be extended to cope. Whereas on a national level, since April this year there has been a new designation of emergency moving up from a *major* incident, officials are now planning for a *'catastrophic'* incident which will require national resources in response.

Overall, the review concludes that in the United Kingdom there remains a great deal more planning and preparation to be done before off-site emergency plans can be considered to be effectively in place and proven. To date (1 November 2002) and although several local authorities are very near to the date when their emergency plans should be in place (mid to late November), of the local authorities approached none had yet had the REPPIR off-site emergency plan in place or, indeed, in the library for public access.†

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† Suffolk County Council (Sizewell) made available a summary Off-Site Plan in late October and during the first week of November documents that seem to be the final off site emergency plan. Lancashire County Council (Heysham) had placed its plan in the Morecambe and Heysham local library, but it would not provide a copy of the plan directly and the library would not photocopy the plan unless it had a letter allowing this from the County Emergency Planning Officer which was not, although requested, forthcoming.

# LOCAL AUTHORITY OFF-SITE EMERGENCY PLANNING AT UK NUCLEAR POWER PLANTS

## RADIATION (EMERGENCY PREPAREDNESS AND PUBLIC INFORMATION) REGULATIONS

From September[1] of this year local authorities have to have in place off-site emergency plans in order to satisfy the requirements of the *Radiation (Emergency Preparedness and Public Information) Regulations* (REPPIR).[2] So that local authorities may prepare adequate off-site emergency plans, the nuclear plant operator at each nuclear site has a statutory obligation to provide a *Report of Assessment*[3] that will enable the Health & Safety Executive (HSE) to determine if off-site emergency plans are necessary and, if so, the geographical area over which these are to be implemented by the local authority. The local authority receives notification from the HSE, thereafter having six months to prepare and fully implement the off-site emergency plan. REPPIR will supersede the operator's obligations of *Regulations 26* and *27* of the *Ionising Radiations Regulations* under which it provides and maintains the existing emergency planning schemes.

The official view[4,5] is that REPPIR establishes a framework of emergency preparedness measures to ensure that members of the public are:

- properly informed and prepared, in advance, about what to do in the unlikely event of a radiation emergency occurring, and
- provided with information if a radiation emergency actually occurs.

Local authorities have duties in REPPIR in connection with off-site emergency plans and making arrangements to supply information to the public in the event of a radiation emergency occurring. They may also be involved in the dissemination of prior information to the public from operators and carriers. The key duties on local authorities are to:

- prepare, review, revise, test and implement an off-site plan for any premises with an operator's plan. The plan should bring together the emergency arrangements of all the off-site agencies with a role to play in the intervention of a radiation emergency occurring at the premises, and
- prepare arrangements to supply information to members of the public in the event of a radiation emergency actually occurring, however it may occur.

These arrangements are intended to cover events such as fallen nuclear-powered satellites, transport accidents or incidents occurring overseas that may also affect Great Britain, as well as from premises and nuclear plants subject to REPPIR. Importantly there is nothing in REPPIR that specifically excludes the local authority off-site plan having facility to respond to terrorist attack and other intentional malicious acts.

The local authority off-site emergency plan has to provide information and arrangements to:

- coordinate the necessary resources,
- assist with on-site mitigatory actions,
- implement off-site mitigatory actions (ie countermeasures), and
- provide the public with specific information about the radiation emergency and the behaviour to be adopted.

REPPIR also sets out a framework for controlling the exposure of employees who are required to intervene in the event of a radiation emergency, for example in saving life or when acting to prevent a large number of people being exposed. Thus the local authority is required

- determine the radiation dose exposures and dose levels appropriate for those putting into effect the emergency plan, agreeing these with the individuals involved and providing them with sufficient knowledge and training so that their dose exposures is minimized.

## LOCAL AUTHORITY OFF-SITE EMERGENCY PLANS

Each local authority off-site emergency plan will have to be tailored to suit not just the relevant nuclear plant(s) in or nearby its area jurisdiction, but account for geographical features, the distribution of population, local and regional road and other transportation. For example, a radioactive incident at Sizewell B power station is likely to demand an entirely different response to, say, a similar incident at Hartlepool. Not only are reactor systems at these two nuclear power stations different (pressurised water reactor and advanced gas cooled reactor respectively), but the population distributions are quite different, with the dense urban population of the town of Hartlepool nearby compared to Sizewell's rural surrounds. In this way, the resource implications, in terms of the management of varying numbers of members of public as these become entrained in the incident aftermath, would be expected to vary from nuclear plant site to site.

Another very important aspect is the speed at which the local authority off-site emergency plan is able to respond to the incident. This aspect of the off-site plan response depends on a number of factors, not just the prevailing wind and weather carrying the radioactive plume from its source, but also the type of incident which must include abrupt and fast moving events erupting without any forewarning. In this category, the local authority off-site plan must give cognisance to terrorist and other acts of malicious intent and, within these, intentions that deliberately hinder incident site control, access to the site and, on a broader front, hamper the local authority's emergency response.

At this time (November 2002) most local authorities with nuclear power plants nearby have yet to publish their off-site emergency plans or to circulate the advance information required to be circulated to members of public. The City of Plymouth and Argyll and Bute have both indicated that they are to adopt the Ministry of Defence public safety schemes that are presently in place at Devonport and Faslane nuclear powered submarine bases, and Suffolk County Council has published a 2 page summary[6] of its off-site emergency plan which is still in preparation.

It is not at all clear how the MoD plans for Plymouth and Faslane can be uncoupled from the disciplined military hierarchal systems, which are well resourced, for transfer to a local authority – such a transfer seems to be almost entirely impracticable. If Suffolk is to be taken as typical of the approach of the local authorities then Suffolk sees its responsibilities to centre around co-ordinating the resources of other organisations, although the summary does not provide any further detail on just how this is to be practicably achieved.

## HAZARDS, RISKS AND CONSEQUENCES ARISING FROM A NUCLEAR PLANT INCIDENT

### IDENTIFYING THE HAZARDS

There are a number of distinct radiological hazards at a nuclear power station, including the fission product and (radio)activated inventory of the reactor fuel and core; the irradiated fuel store; and radioactive wastes from past operations being stored at the station – these separate inventories will vary from station to station, depending on the plant size and type, and its operational history. Other nuclear plants and activities, such as the reprocessing plant at Sellafield, the fuel works at Springfields, and military plants at Aldermaston and nuclear submarine refit ports such as Devonport in Plymouth, will have a different composition of radioactive inventory and there might be, depending on the particular plant, a narrower or broader range of radiological hazards.

Considering an operational nuclear power station the hazards might be broadly grouped as follows:-

- **Nuclear Reactor:** Loss of reactor pressure vessel containment boundary, depressurisation and release to atmosphere of coolant gas/water of moderate radioactivity, subsequent failure of fuel element cladding and release of fission products of significant levels of radioactivity, including aerosols and particulate matter, possibility of channel fuel fires at Magnox stations - potential for a very high and energetic level of radioactive release, ie Chernobyl/Windscale scale.

- **Irradiated Fuel Storage Ponds:** Minimal containment and few safeguards against external (terrorist) attack, loss of water/cooling supplies to fuel ponds, overheating and/or physical disruption of fuel, possibility of fuel fire at Magnox stations – potential for a very high level and energetic (Magnox) level of radioactive release.
- **Radioactive Waste Store and Treatment Plants:** Once processed and packaged, relatively small batches of radioactive wastes available for release, some waste streams volatile and flammable, unprocessed and unpackaged Magnox splitterings waste held in large volume vaults with potential for fire and energetic release – potential for moderate level radioactive releases.

If the delivery and removal of fuel, and the removal of radioactive waste, from the power station are taken into account, then the additional hazards should be considered:-

- **Irradiated Fuel Transportation:**[see 12] Fuel flasks involved in railway incident, loss of flask containment, fuel overheating and release, possible fuel fire for Magnox, could occur in densely populated urban areas – potential for moderate release and large numbers of individuals at risk of radiation exposure.
- **New Fuel Delivery:** Road traffic incident, containment failure, possibility of criticality incident – potential for low to moderate levels of radioactive release, but could include high levels of short-lived fission products.
- **Radioactive Waste Transport:** Road traffic incident, presently confined to low-level waste consignments – potential for relatively low levels of radioactive release.

For nuclear power stations that have ceased operating and are undergoing decommissioning, storage and dismantling the hazards include:-

- **Radioactive Waste Store and Treatment Plants:** Generally as above for an operating power station.
- **Intrusion, Fires and Vandalism, Etc:** The potential for radioactive release from incidents arising during the period of decommissioning (which might extend 100 years or more), including fires and releases accidentally initiated during the dismantling processes or from illegal intrusion, vandalism and other acts of damage when the reactor hulks are under institutional care.[7]

### FORESEEABLE FAULTS AND INCIDENTS

For each of the hazards previously (and generally) identified the nuclear plant operator would have determined groups of foreseeable faults. Some of these faults would be plant/equipment specific, for example the failure of a valve or some other piece of equipment, and other faults could apply to the whole plant, such as an earthquake, flooding, aircraft crash, etc.. These types of faults can be quite reliably specified in terms of frequency of occurrence mainly from information drawn from past performance and incidence rates (*post priori*).

Terrorist, malicious and other human acts cannot be reliably predicted from a *post priori* basis. In any one year or one decade, the risk of such an act might not be considered to be credible, whereas in another decade the risk might be realised and continue thereafter to be credible. Post 11 September terrorist acts now have to be considered to be credible not simply because such an attack took place on 11 September 2001 but because, here in the United Kingdom, the threat of such an attack continues and, in fact, presently may be heightened.

Under REPPIR the operator is required to identify all reasonably foreseeable situations that could give rise to a radiation emergency. This requires the operator to, first, identify all hazards and, second, evaluate the nature and magnitude of the risks arising from these hazards. This is required in the form of the Report of

Assessment submitted to the Health & Safety Executive (HSE) which then notifies the local authority of the need for and extent of the off-site emergency plan.

Although REPPIR is tacit on terrorist attack (mainly because the regulations were compiled before 11 September 2001), the general responsibilities of the operator and the local authority must include for such intentional acts within the requirement to account for all reasonably foreseeable situations. This is important because:

- **Uniqueness of Terrorist Actions:** A terrorist attack would be a unique action, being an intelligent and intentional act. This means that parts of the nuclear plant and its equipment not considered to be vulnerable or at risk from accidents and plant malfunctions, may be specifically targeted by the terrorist in such a way as to maximise the disruption.

  For example, two pieces of equipment might be physically isolated but an 'insider' might connect these (electrically, mechanically, hydraulically or however) to create a unique malfunction that the plant's safety systems was not designed to recognise.

- **Off-Site Impact:** Whereas, as chance would have it, an accidental situation might not result in a radioactive release to the off-site domain, a terrorist act might be specifically designed to maximise the off-site impact of any radioactive release. This might be done to maximise the psychological and economic impacts of the incident.

  For example, the incident might be timed to correspond when the least stable atmospheric conditions are most likely to prevail.

Or, indeed, the attack might be implemented by an 'insider' able to access crucial control systems, reactor emergency cooling circuits, or similar key equipment and safety systems.

### IMPLEMENTING THE OFF-SITE PLAN

Obviously, the first task of the local authority emergency planning officer, or whosoever administers the off-site plan,[8] would be to assess the elements that make up the immediate development phases of the incident. This requires giving particular regard to the radionuclide inventory, path of the radioactive release, its dispersion and eventual deposition. These considerations will enable the following to be determined:

| **INCIDENT IMMEDIATE DEVELOPMENT PHASE** | | | |
|---|---|---|---|
| ELEMENT | FACTORS | MECHANISMS & PROCESSES | OUTCOME |
| **Radioactive Inventory and Release Fractions** | Amounts and types of radioactivity (the inventory) available for release, proportion(s) released (release fraction) and the conditions (energy, temperature, volatility, etc) of the releasing substance upon its release. | Continuing and/or introduced nuclear processes (ie criticality) - energy input for the initiating event or immediate post-event conflagration - building contents and/or stored substances (radioactive wastes/fuel) fires | The magnitude and types of radionuclides involved determine the totality of potential health harm and levels of contamination, the overall radiotoxicity and its persistence in the environment. The release fractions are critically dependent upon the circumstances of the incident, particularly the energy level of the disrupting event, obviously the extent of the containment breach and the incident and immediate post-incident chemistry. The mechanisms and processes involved in the initiating and immediate post-incident train of events will determine the strength of the radioactive emissions, particulate and aerosol, that make up of the release. |
| **Radioactive Release Path** and **Dispersion and Deposition** | The height of the release above the ground, the subsequent lofting of the plume until wind shearing sets the radioactive cloud, and dominantly the wind direction, the cooling and/or inversion of the plume and its deposition on ground and other surfaces | Initial energy of the release (heat input or explosive puff) – meteorological conditions at the point of release – downwind conditions – local terrain factors – atmospheric stability which is categorised in 7 conditions ranging from *extremely unstable* or *A* to *extremely stable* or *G*[9] | The physical characteristics, setting the height of the release, thereafter plume lofting is determined mainly by the energy (temperature, etc) of the release situation so the location of the containment breach is important, the heat input (or puff explosion) and the prevailing meteorological conditions can extend the range of the plume or bring it down locally around the release site. Natural variations in meteorological conditions can result in orders of magnitude changes in the dispersion patterns and the total numbers of individuals at risk. |
| **Uptake and** | The uptake paths and the | Sheltering, respiratory | For effective sheltering the physical characteristics of the |

| | | | |
|---|---|---|---|
| **Exposure** | exposed individuals, identified as critical groups | protection and prophylactic means to mitigate dose exposure | radioactive plume and atmospheric conditions have to be known, sheltering may be virtually ineffective in well ventilated and/or air conditioned buildings, distinctions may have to be made with critical groups, particularly for radioiodine prophylactic measures and respiratory protection may be essential for groups waiting evacuation – self evacuation may create chaos and result in an increase dose exposure. |

However, REPPIR relies upon the operator (or carrier) to provide a provisional assessment of the situation and consequences of the incident (*Reg 13(3)*), but this assumption may be invalidated if the operating staff are somehow incapacitated or, for example, if communications are down. In these circumstances the local authority itself would have to assess the aftermath of the incident that may be developing rapidly. In fact, in a recent table top exercise,[10] an incident was initially notified by the (Bradwell) power station to the emergency control centre in the absence of any information whatsoever on the type of incident, wind direction, wind speed and, later in the exercise real time, the water utilities were unable to make decisions on potable supplies because the radionuclide inventory of the plume (and the extent of the plume) was unknown.

Similarly, in the case of Suffolk where it relies upon the NRPB to provide monitoring data and on the specific options to reduces radiation dose exposure to the public,[6] it might find that this organisation cannot respond quickly enough, nor in sufficient detail, to enable mitigation measures to be implemented to safeguard the local population in the immediate aftermath of an event leading to a radioactive release. Whatever, it remains the responsibility of the local authority to provide the arrangements for mitigating off-site consequences, so it must be assumed that local authorities will provide contingency for the absence of advice and instructions from such bodies as the NRPB and the Government Technical Adviser who is appointed after the seriousness of the incident has been assessed and who may be some hours arriving in the incident locality.

There is nothing in REPPIR that specifically addresses the circumstances in which the local authority has to respond in the absence of sound information from the operator (carrier) or other specialist bodies. In these circumstances the local authority may not have sufficient resources or knowledge to implement the initial and immediate stages of its off-site emergency plan. As discussed later, the effectiveness of the initial phases of the emergency response is critical for safeguarding the health and wellbeing of members of the public.

### IMPORTANCE OF THE INITIAL RESPONSE TO RADIOLOGICAL INCIDENTS

REPPIR defines a radiological emergency as the receipt of 5mSv of effective dose[11] within the period of one year immediately following the incident. The off-site emergency plan has to be implemented to deal with an incident which leads to, or is likely to lead to, a member of the public receiving a dose above 5mSv over the following one year period. The 5mSv level should not be confused with the actual radiation dose exposures to members of public within the radiation zone of a declared emergency area, even with countermeasure actions such exposure could be considerably higher than 5mSv.

Obviously, for relatively small scale releases of radioactivity there is likely to be sufficient time to incorporate incident-specific countermeasures within the off-site emergency plan in order to minimise the radiation exposure. Such countermeasures might include evacuation and/or sheltering, decontamination and change of use of particular areas of land, etc..

The first few hours following the initiating event is considered to be the 'critical' phase for both the on- and off-site responses, when key decisions have to be made. These key decisions could greatly affect the success of any mitigation/countermeasures. Importantly, these decisions may have to be made within a relatively short period of time when those responsible might be under considerable pressure. So, in the event of a significant and, particularly, an abrupt radioactive release, if countermeasures are to be at all effective they must be implemented very quickly, where possible in advance of the arrival of the radioactive plume and fall-out (deposition). It is the effective implementation of this first phase of the off-site emergency plan that is so critical to the well being of members of public in the locality of the nuclear plant.

This Review considers the first few hours following the initiating event – this is the period when, most of all, the local authority off-site emergency plan will have to stand alone, that is be sufficient in itself to make the appropriate decisions and implement the correct countermeasures and actions to safeguard the health and safety of the public at large.

**FIRST PHASE RESPONSE TO AN EXAMPLE RELEASE**

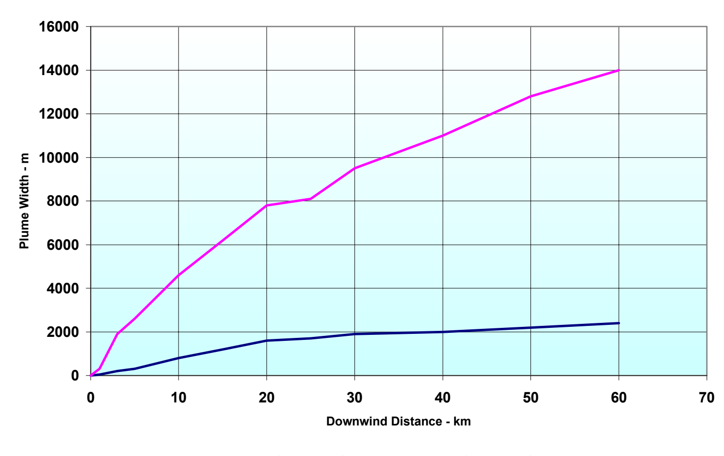
Consider an example release arising from an incident involving an equivalent of 1 tonne (uranium) of light water reactor fuel irradiated to 30MW days per ton. This might also be taken as an equivalent of about 20% for Magnox fuel on account of the lower irradiation or burn-up rate of Magnox fuel, although due to the greater proportion of the U-238 isotope in Magnox fuel the actinide content will be greater by about 5 to 10%.

In this example the fuel is considered to be in transit at some location between a UK power station and the British Nuclear Fuels reprocessing works at Sellafield, or it could be overseas fuel being imported into the port of Barrow for onward transit by rail to Sellafield.[12] Alternatively, an equivalent mass of fuel could provide the source term for a release from an operational power reactor (but including the impact of shorter lived radionuclides and, particularly, radio-iodine), from a fuel storage pond or, more generally, from dispersion of a much larger mass of intermediate-level wastes stored at any one of the many sites across the UK.[13]

For an abrupt radioactive release consider a situation whereby irradiated fuel in transit is somehow caught in a railway tunnel fire. This situation might arise from a derailment and collision with a chemical or petrol tanker train in the tunnel. A similar but intentional situation might arise whereby terrorists intentionally stop and hold an irradiated fuel train in the confines of a tunnel and then introduce explosives and/or flammable materials sufficient to breach the flask containment. Recent tunnel fires (Derbyshire Summit Tunnel, Channel Tunnel, Mont Blanc and others) have all demonstrated the very high and sustained temperatures that are achieved in confined spaces, and failure of the current designs of Type B irradiated fuel flasks to prolonged exposure to high temperature is well documented.[14] The effective release height of the radioactive plume is assumed at 50m, although thermal lofting to a greater height, which is likely in a severe fire especially where the tunnel air vents act as flues, would result in exposure to a greater number of individuals at greater distances from the site of the incident. For the analysis, the fire duration is assumed at 10 hours overall, with the radioactive release occurring at 3 hours into the incident, so the release duration is 7 hours.

For steady state weather conditions the resulting dispersion plume for a rough terrain model of a townscape develops as follows:-

**Figure 1 Development of Release Plume**



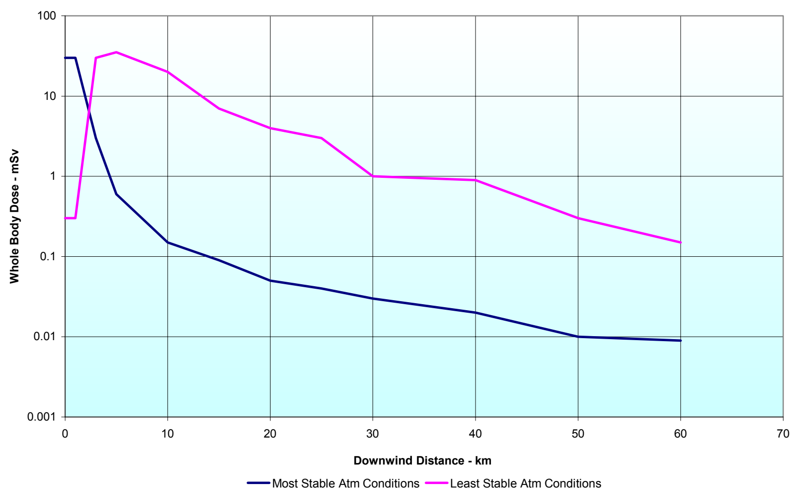

The plume development is shown for the extremes of atmospheric stability so the expectation is that the plume will develop at or between these extremes. It is under this plume that the immediate radiation exposure occurs.

The majority of the persons at risk of exposure are the residential population, although in areas of high commercial activity, the workforce might feature strongly in the exposed group.

Here we are considering the period of the release and its immediate aftermath. During the actual release of duration of 7 hours, the exposed individuals would be subject to exposure from the cloud of radioactive emitting particles undergoing dispersion (cloudshine), from inhalation of these (internal uptake), and from radiation shine from those particles that had settled on the ground, building and other surfaces (groundshine). Thereafter, those individuals remaining in the area of particle deposition would receive further exposure from groundshine so long as they remained in the area.

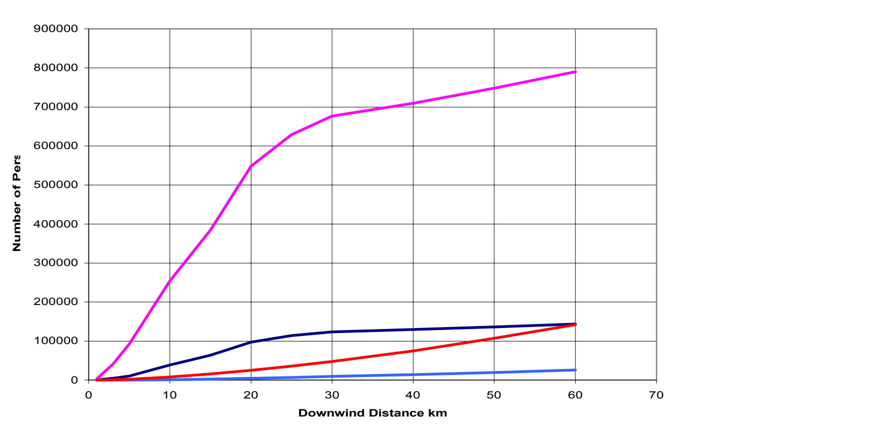
On the basis that it might take the local authority up to one day to organise, apply and, importantly, clearly communicate the requirements of its off-site plan to members of the public, there might not be any effective countermeasures in place for the majority of the exposed population for up to 24 hours from the onset of the radioactive release. Taking a one day (24 hour) period for the short-term radiation dose from all sources (including 7 hours of cloudshine), the individual radiation exposure for *most* and *least* stable atmospheric conditions is:-

**Figure 2 Fuel Flask Fire - Magnox - Short Term 7/24 hour Dose from All Sources**




The number of individuals at risk of exposure relates to the distance from the incidence and population density which, for urban and rural localities are as follows:-[15]

**Figure 3 Urban and Rural Populations Exposed**



In this example incident the least stable atmospheric conditions extend the area of significant levels of short term dose (say >=1mSv) to about 30km under the plume shape, so the numbers exposed for typical urban and rural population distributions range from possibly up to about 700,000 for a densely populated urban area such as London and, obviously much lower, for a rural area, say, Suffolk centred around an radioactive release incident at Sizewell nuclear power station, where up to about 30,000 persons may be subject to significant short term radiation exposure.

### ACCEPTABLE RISKS – THE PROBABILISTIC BASIS OF THE ERLS

In radiation emergencies mitigation and countermeasures are implemented in order to avert levels of radiation dose exposure to individuals and critical groups of individuals. These levels are prescribed by the NRPB[16] and are referred to as *Emergency Reference Levels* (ERLs), being applied to the total exposure or *whole body dose*, and the *single organ dose* which is particularly applied to the thyroid uptake of radioactive iodine ($I^{131}$).

The lower ERL is defined to be the level of dose below which no benefit would arise if countermeasures were implemented. The upper ERL is the level of dose that should be averted and not exceeded by the implementation of appropriate countermeasures. Both ERLs by far exceed the natural background radiation levels and individuals subject to these levels of radiation exposure would in a relatively short time be exposed much above that permitted annually (1 mSv/year).[17]

These ERL based composites are those adopted by the HSE and NRPB in setting out guidance on levels of public exposure to radiation.

### TABLE 1 EMERGENCY REFERENCE LEVELS

| | NRPB EMERGENCY REFERENCE LEVELS mSv[18] | | | |
|---|---|---|---|---|
| | LOWER | | UPPER | |
| **COUNTERMEASURE** | **WHOLE BODY** | **ORGAN** | **WHOLE BODY** | **ORGAN** |
| **SHELTERING** | 3 | 30 | 30 | 300 |
| **STABLE IODINE TABLETS PITS** | - | 30 Thyroid Only | - | 300 Thyroid Only |
| **EVACUATION** | 30 | 300 | 300 | 3000 |

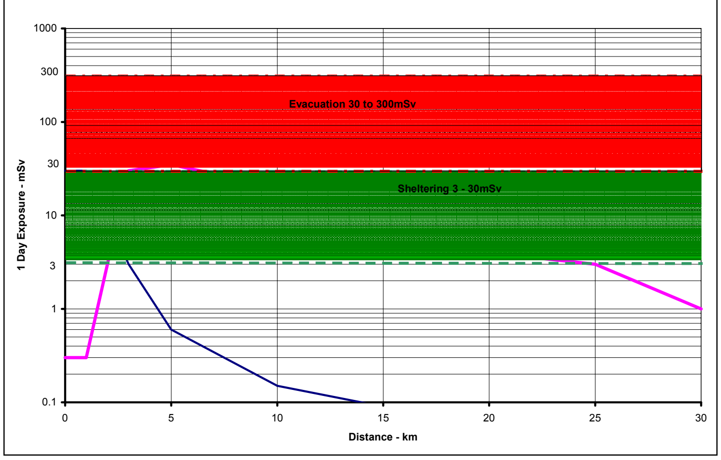
For example, considering the whole body or effective radiation dose exposure (as shown in Figure 2), if the exposure is kept below the upper ERL then the consequences to any individual exposed might be considered to be *'tolerable'* (although there is some debate about this). It follows, if the frequency of such a radioactive release is predicted by probabilistic means (as is the present approach for nuclear 'accidents'), the *'acceptable risk'* of intolerable radiation exposure might be expressed as a chance linked to the probabilistic forecast for accidental releases of radioactivity. However, whereas probabilistic means might be applied to forecasting 'accidents' this approach is entirely invalid for acts of malicious intent, that is terrorist attack and sabotage.

The effectiveness of operating ERL based countermeasures is critically dependent on being able to accurately forecast the development of the radiation dose from the onset and throughout the aftermath of the accident. If countermeasures are introduced too early, below the lower ERL, then scarce human and equipment resources may be wasted. On the other hand, triggering the countermeasures too late could result in high and unacceptable dose receipt by critical groups of the exposed population.[19]

So, in implementing the off-site emergency plan, first the local authority has to be able to predict (or be advised by the operator and/or NRPB) that the conditions of a 'radiation emergency' exist (*Schedule 1*) and then, once the Radiation Emergency is declared, it has to set about coordinating implementing the appropriate countermeasures as these are triggered by the ERL thresholds.

For the fuel flask release previously exampled and which will not have a significant radioiodine constituent,[20] the local authority would need to implement countermeasures within the first 24 hours following the incident as determined by applying the Whole Body Dose ERLs to Figure 2:-

Figure 4 30 km Zone ERL Thresholds




For this scale of radioactive release and under least stable conditions, members of the public out to 25 km from the incident centre would be advised to shelter (stay indoors) and those located between 3 and 6 km would be in the zone at risk requiring to be evacuated. For an incident centred in an urban area the numbers of individuals requiring to shelter could be as high as 650,000 and those individuals requiring consideration for evacuation would be of the order 20,000 to 30,000, depending on conditions established in the locality at the time.

For the most stable atmospheric conditions, on the basis of the ERLs no individuals would require evacuation and the sheltering requirement would extend out to about 3 km from the release site which, for a densely populated urban area might require 2,000 or more individuals being considered for evacuation.

If the irradiated fuel release considered here could only have arisen from circumstances that were either truly accidental or related to the occurrence of a natural hazard, then it might be possible to assign a probability or chance of the event occurring.[21] Furthermore, once the probability of the event occurring has been settled, the consequences of the aftermath of the event might be further attenuated by applying the probability of which atmospheric stability condition will likely prevail at the time of and during the release and dispersion phases of the event. The probability of occurrence of each category of atmospheric conditions for the southern area of the UK (Heathrow) is usually assumed to be:-

| STABILITY CATEGORY | RAINFALL RATE mm/hr | WIND SPEED m/sec | PROBABILITY |
|---|---|---|---|
| A | 0 | 0.5 - 1.0 | $3.20.10^{-4}$ to $1.04.10^{-3}$ |
| B | 0 | 0.5 - 4.0 | $1.02.10^{-2}$ to $2.57.10^{-3}$ |
| C | 0 to 5 | 0.5 - 10.0 | $3.09.10^{-3}$ to NIL |
| D | 0 to 5 | 0.5 - 10.0 | $1.25.10^{-2}$ to $3.60.10^{-4}$ |
| E | 0 | 2.5 - 4.0 | $4.34.10^{-2}$ to $3.77.10^{-2}$ |
| F | 0 | 0.5 - 2.5 | $2.85.10^{-2}$ to $2.91.10^{-2}$ |

that shows that generally the most stable atmospheric conditions (ie smaller plume and least number of individual exposed) are more likely to prevail (on average about 100 times more) than the least stable conditions. Applied to Figure 4, the *likelihood* is that stable atmospheric conditions will apply at the time of the release and that the consequences will attenuate.

### RECOMMENDED CHANGES TO THE IODINE ORGAN DOSE ERLS

In a second example of a radioactive release consider a release emanating from nuclear power station at which the releasing nuclear reactor was, until the initiating event, in operation. Again, the actual event scenario and the amount of radioactivity release is not important, other than the radioactive plume will contain a particular radionuclide iodine-131. This example illustrates two important features of the need to have effective measures in place during the first phase (24 hours) of the emergency.

**Figure 5a PWR Moderate - 1st Day Effective Dose**

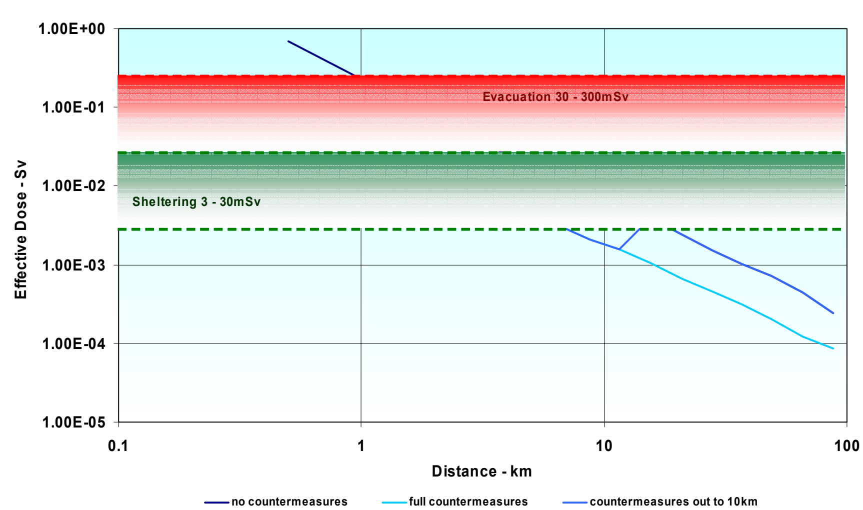



Figure 5a shows the result of effective early countermeasures on the whole body or effective dose exposure (24 hours). In this example, a potential 1st day dose is reduced from about 300mSv to 70mSv by a combination of evacuation and sheltering (top and lower data lines). If the extendibility of the off-site plan is curtailed at 10 km then, without countermeasures, the public dose levels remain in the sheltering zone from 10 km out to about 20km.

**Figure 5b Thyroid Organ Dose**

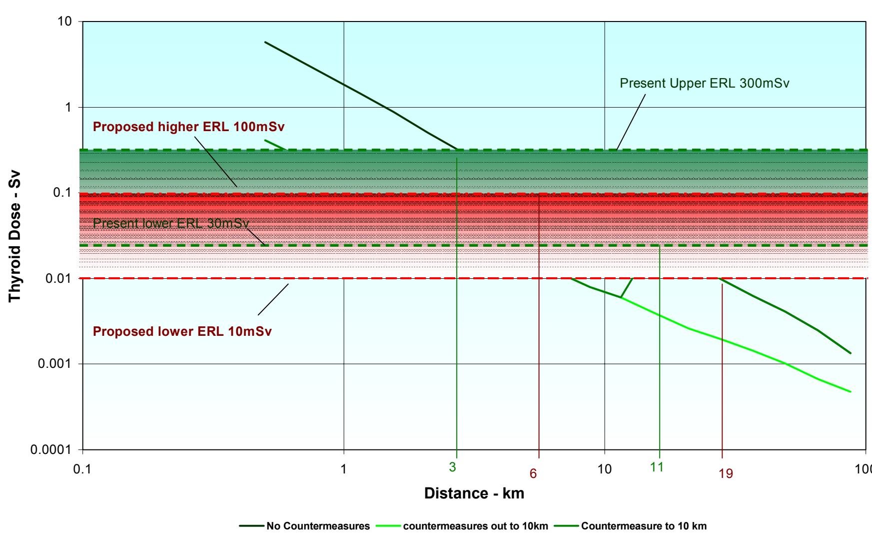


Figure 5b show the outcome of a change in the thyroid organ dose ERLs. For a reactor plant that has a recent history of power operation, any radioactive release will include the gaseous fission product iodine ($I^{131}$) that, via inhalation, is available for reconcentration in the thyroid gland. This, to a certain extent, may be countered with iodine introduced by prophylactic potassium iodate tablets (PITs) taken orally in advance of the arrival of the plume carrying the radioactive iodine exposure if the thyroid blockage is to be effective.[22]

Applying the present NRPB ERL recommendations (lower/upper 30/300mSv) to this example scenario, PITs would definitely have to be issued out to 3 km to counter the 1st 24 hour dose exposure uptake and readiness to issue PITs would have to be maintained out to 11km. However, if the recent recommendations of WHO and the NRPB[16] are applied, the ERLs revise to 10mSv lower and 100mSv upper for which this example scenario requires PITs to be consumed by those within a 6km radius of the incident and held in readiness out to a radius of 19km.[22] In terms of numbers of individuals potentially exposed, the respective increase of populations requiring PITs issue and readiness is x4 and x3 respectively.

Particularly for large numbers of population, accessing and administering PITs may present difficulties. In the recent Bradwell ISIS Level 3 extendibility exercise,[10] although the radioactive release was notified as a radiation emergency at 06.40 hours and the decision to administer PITs was made at 09.00 hours, stocks of tablets could not be accessed until 14.20 hours, that is some 8 hours following the potential for radioiodine uptake. Even once accessed, administering PITs to members of public would have taken a few more hours, with such an overall delay that much of the thyroid blocking effect of stable iodine must have been rendered ineffective.

As previously noted, depending on the actual locality and population present, a relatively small extension of the off-site DEPZ can result in many thousands requiring, in this case, stable iodine prophylactic measures.[16,30]

**RESPONSIBILITIES OF THE LOCAL AUTHORITY**

A number of local authorities seem to consider their responsibilities under REPPIR to be essentially confined to that of coordinating existing resources, which may or may not be adequate to respond to all reasonably foreseeable emergencies. However, it is clear that REPPIR extends beyond this, requiring the off-site plan not only to be adequate but also fit for purpose for all reasonably foreseeable incidents. The operator is required to identify all *reasonably foreseeable* incidents, not just notifying these to the HSE but also providing the local authority with such information that is necessary to for the off-site plan to be prepared and maintained (Reg 9.4/5).

There are a number of points of interest that arise from this probabilistic approach to setting the severity of the release, the countermeasure thresholds and potential consequences:

a) **Acceptability of the ERL Strategy:** First, there is the assumption that members of the public will accept the rationale that the higher dose exposure levels imbedded into the ERLs are justified in account of the likelihood of the event occurring in the first place and, when it occurs, that the atmospheric conditions will be most clement – that is the higher ERLs are justified by including a strong element of risk dependency. Indeed, not only will most individual members of the public have no knowledge of the ERL system, they are unlikely to be able to grasp the units, implicit health risk and detriment, and types of exposure accounted for in the ERL strategy. Particularly, individuals may not be prepared to accept a system of countermeasure initiation drawn from societal risk reasoning.

   The local authority is responsible for providing members of the public with advance information that gives local householders and others clear understanding of the actions that they might be asked to take in a radiation emergency, although the basis for taking such actions (ie the ERLs) is not cited in the *Reg 16* or *Schedule 9* to which it relates. This information is to be made available with publication of the off-site emergency plan and not just at the time of the radiation emergency.

b) **Forecasting the Development and Severity of the Radioactive Release:** In the immediate aftermath of the event, in order to implement the ERL countermeasure strategy the local authority will need to forecast in advance how the radiation dose exposures are developing.[23] For this it cannot rely entirely upon the plant operator or carrier who may not be monitoring much further afield than the centre of the incident site, and/or the NRPB might not be able to address the situation quickly enough with personnel and equipment for timing or distance reasons (ie weekends and travelling to the site). If so, the local authority itself will need to assess the developing radiological situation to arrive at its ERL forecasts before it can move to implement its ERL triggered countermeasures. However, for this it may not have sufficient, if at all, gamma spectrometry monitoring systems in place locally, and/or the expertise to run the relatively sophisticated predictive dispersion software analysis and to apply the results.

For the local authority to depend entirely upon the operator and/or the NRPB to forecast the severity and development of the radioactive release may sacrifice vital hours in the early phases of the release when countermeasures might need to be implemented. Weaknesses in this dependency were highlighted during the recent Bradwell Isis emergency exercise[10] when insufficient information on the incident and the radioactive release plume at the commencement of the incident later meant that the local water utility required to advise users on any controls arising from potential contamination of potable supplies could not fulfil its role.

c) **Extending the Off-Site Plan:** If the event occurs in or nearby a densely populated urban area, then the local authority REPPIR off site emergency plan is unlikely to be able to extend much beyond the 10km extendibility zone (some would argue the REPPIR plan might not effectively extend much beyond the 1 to 2km DEPZ or Detailed Emergency Planning Zone) in which most off site plans will trigger countermeasures automatically. The ability of a local authority to apply countermeasures to potentially very large numbers of the public is fraught with practicable difficulties and would, more likely, quickly exhaust the local authority and emergency services' (firefighters, ambulance crews and police) human and equipment resources.

In fact the basis of maintaining a relatively small DEPZ of typically 1 to 3 km is that countermeasures in this zone can be preplanned and triggered automatically, that is relieving the local authority of the task of determining and forecasting radiation exposure as these might rapidly develop. Extending the off-site emergency plan is justified on the basis that because *'the improbability of a larger incident and release means that that the absence of a detailed plan would not significantly increase the risk to the public'*.[24] In effect, this reasoning is based on the assumption that the occurrence of a larger (significant) radioactive release is of such low probability that the likely less effectiveness of having largely unprepared plans in the extendibility area, with the attendant more severe consequences, will be acceptable to members of the public.

In fact, it was considered by this same reasoning to apply to terrorist attacks, that such malicious acts of intent could be considered on a probabilistic basis,[24] although the basis of such reasoning would be considered by some to be deeply flawed.

d) **Self-Evacuation by Members of Public:** An uncertainty in any radiological situation is the public response to advice and direction issued by the local authority in the context of the general public perception of the risk and consequences of being ensnared in a radiation incident. As already noted, it will be practicably impossible for the local authority to cater for the immediate needs, in the form of information and advice, and/or specific countermeasure implementation, when large urban populations are involved. In the case of the hypothetical irradiated fuel transportation accident being considered as an example here, even if only a relatively small number of individuals (say hundreds or a few thousands) require direction and assistance, many others close by are likely to take such action as they individually believe to be expedient and appropriate to safeguard their families and themselves. In the aftermath of the Three Mile Island incident of 1978, the US Nuclear Regulatory Commission publicly announced its recommendation that breastfeeding mothers and neonates residing in the locality should evacuate, but during that night and through the following day over 480,000 individuals chose to self evacuate.

Such a massive self-evacuation in a UK urban area would, no doubt, result in near absolute chaos and traffic gridlock, as well as the spread of contamination and difficulties for the health and other services involved with the post-incident treatment of those contaminated. The ability of the National Health Service hospital and ambulance trusts has been subject to much criticism for its state of ill-preparedness by the National Audit Office[25] and more generally the House of Commons Defence Committee.[26]

e) **Protection of Employees and Workers, etc:** There might be three different categories of employees involved in the off-site emergency actions: 1) Those involved in urgent actions at the scene of a serious incident; 2) those involved in implementing countermeasures and taking other actions to protect the public; and 3) those involved in recovery operations.

(1) **Lifesaving, etc:** For the individuals in the first category there is confusion as to the appropriate maximum dose limits to be applied: The NRPB consider and recommend that for those who must act to save life, to prevent serious injuries or to prevent a substantial increase in the scale of the accident, it is neither possible nor appropriate to specify maximum levels of dose for such situations, and the NRPB goes so far as to recommend only that substantial efforts be made to keep doses to these workers to levels lower than those at which serious deterministic health effects may occur (~500mSv or higher).

On its part, the HSE interprets regulations 14(2), 14(3) and 14(4) not to mean that disapplication of the dose limitation system (Reg15) to be a general amnesty on the need to control dose up to the notified dose levels for emergencies, suggesting emergency dose levels up to 100mSv effective (1000mSv skin and 300 mSv eye lens) to be acceptable. The HSE adds that specific provision may be made explicitly for life saving of up to 500mGy effective (~500mSv and 5,000mSv for skin), recently changing this from 250mSv in its provisional guidance without any explanation.

However, the three emergency services likely to be involved in lifesaving and similar 'front line' activities each adopt quite different approaches to dose limitation. On their part, the firefighters have national agreements that the radiation dose exposure at any single incident should not exceed 50mSv, or up to 100mSv for instructed lifesaving (there being no voluntary actions to be undertaken by firefighters) and, although this applies to individuals, the entire firefighting team would withdraw if any member of that watch was exposed to the 50mSv limit. Ambulance personnel and paramedics attending would be required to adhere to the Ambulance Services Association[27] which is that of *"zero tolerance"* (ie no radiation exposure whatsoever) and the police, as given by the Police Federation,[28] have no national system in place.

It is only the firefighters that have radiation specific training and personal protection equipment (breathing sets and contamination suits) which, together with their training, provides them with proficiency in a radiological environment.

(2) **Higher Exposure Employees:** These employees are generally assumed to be those workers classified to work with radiation under the Ionising Radiations Regulations, being Classified as being likely to receive an effective dose in excess of 6mSv per year or an equivalent dose which exceeds three-tenths of any relevant dose limit and shall forthwith inform those employees that they have been so designated. Normally, these individuals would be employed at the local nuclear plant or elsewhere in the nuclear industry and not be in the employ of the local authority and either of the three emergency services, although depending on the demands being placed at the scene of the event, a number of classified individuals might be seconded to the off-site emergency plan.

Now the NRPB argues that since this activity results in deliberate exposure which, to some extent will be controlled, this dose regime might also be applied to employees of the local authority and to each of the three emergency services, although this must be subject to the regulations: 14(1): – a) individuals are previously identified in the emergency plan, b) they be provided with training in radiation protection, c) provide appropriate levels of equipment, and d), e), f) & g) record and oversee the emergency exposure. Moreover, the NRPB considers that for these employees since accidents are not expected to occur very frequently, that it would be appropriate to allow employees in this second category to receive doses which are greater than routine doses to occupationally exposed persons.

(3) **Employees Restoring Normal Conditions:** The actions of the workers in the third category are important in restoring normal conditions but they are not so directly concerned with protection of the public as those of workers in the second category. The NRPB recommends that the full system of dose limitation for occupationally exposed persons should be applied to these workers.

It is only the NRPB that defines and distinguishes between these three groups of employees. In its advice, the HSE makes no such distinction with its guidance which applies across all employees, irrespective of their employer, radiation worker classification and, indeed, experience in such matters although each employee must agree to undergo the emergency exposure (Reg 14.5b).

The ambiguity over the appropriate levels of dose limitation may lead to a number of difficulties in the practicable implementation of any off-site plan.

Obviously, the three emergency services and the plant operator's employees are those individuals who are most likely to have to work in high radiation environments, particularly at the centre and close to the scene of the incident. Difficulties on and about the incident site could add to the severity of the radiological situation in the off-site domain and this remains a risk so long as there are such stark differences in the radiological protection arrangements (indeed, where such are actually in place) adopted by the individual emergency services.

If, as seems to be the requirement, local authority employees will have to be drafted in to practicably implement the off-site plan, then these individuals are likely be considered as Category (2) employees for whom a higher dose regime is considered to be appropriate – to reiterate, the NRPB suggest that these individuals might be allowed to be exposed to at least the occupational levels of nuclear employees, if not higher.

Unless the local authority is specifically able to exclude all of its employees, then it must identify those of its employees who might be required to operate at these higher dose levels (Regs 14.5 and 14.7). If it does this, then it must set aside adequate training and equipment for these individuals, maintaining this equipment at the ready at all times.[29]

Obviously, the numbers of local authority employees likely to be required to support the off-site emergency plan will be set by the prevailing circumstances. It might be possible for the local authority to identify the numbers required to support off-site actions confined to the 1 to 3km DEPZ, but once the countermeasure requirement extends beyond this zone, supporting numbers will increase in proportion not just the area but to the population requiring direction and support. At localities such as Hartlepool and at the nuclear powered submarine base at Plymouth or, indeed, at any densely populated area in which a transportation incident could occur, a relatively small extension of the countermeasures zone could involve thousands and possibly tens of thousands more people in the off-site plan.[30]

## CONCLUSIONS

This Review set itself three objectives. These were

1) is there sufficiently detailed information available in the public domain to assess the viability and effectiveness of the REPPIR local authority off-site emergency plans;

2) do the local authority off-site emergency plans cover all possible incidents and events that could result in a release of radioactivity into the off-site; and

3) are such plans realistically extendible to cover abrupt releases, severe releases and releases initiated by malicious action, such as terrorist attack?

### Information Accessibility

From our inquiries no local authority has yet to publish its final REPPIR off-site emergency plan[but see footnote ‡]. This is surprising because a number of authorities have to have their plans in place by mid to late November 2002.[2]

Again from local inquiries, very few members of public and special interest groups have been directly consulted by the local authorities during the preparation of the off-site emergency plans, with the consultation being limited to nuclear plant local liaison committees and similar 'representative' bodies. REPPIR requires the local authority to undertake consultation (Reg 9.12) although it has the option to *"consult with such persons, bodies,* *authorities and members of the public as the local authority considers appropriate.".* Obviously, many local authorities do not consider members of public and local interest groups to be 'appropriate persons' for such consultation.[31]

As part of the prequalification process the operator has to prepare a Report of Assessment identifying all reasonably foreseeable incidents that could result in a Radiation Emergency. Each individual Report of Assessment is considered by the HSE who then specify the extent to which the DEPZ is to apply.

Our requests for copies of the reports of assessment have been met with a series of promises to provide although very little information has been forthcoming. For example, the Ministry of Defence cannot release its assessment of Devonport until it itself has removed 'sensitive' information, which beggars the question of how much and in what detail will the information that it is prepared for release to the local authorities enable them to put in place realistic plans. British Energy, although prepared to release its assessment reports, has yet prepare these in a format suitable for public release, and British Nuclear Fuels and its Magnox division has no intention of making its assessment public.

The Ministry of Defence made available (15 November 2002) its report of assessment for the submarine Z berth at Southampton.[32] However, this assessment provides no details whatsoever of the radionuclide inventory of potential release scenarios, the types of release scenarios themselves, and how these are likely to develop. This declassified version is to be provided to the local authority to enable it to prepare its off-site emergency plan (Reg 9.4)[33] although just how useful this extremely scant and somewhat contrived hazard assessment will be is open to speculation.

The HSE has a clear role of specifying, for each nuclear facility, if and to what geographical extent the local off-site emergency plan is to apply. For this it notifies each local authority with a stereotype one page letter that provides no explanation whatsoever of how it has reached its decision. Without explanation the HSE system throws up and seemingly endorses a number of anomalies with no apparent rationale as to why near identical AGR power stations at Heysham and Hartlepool have DEPZs of 1km, whereas that at Torness requires a DEPZ of 3km.

Overall, during the preparation period for the local authorities to implement their REPPIR responsibilities, the dissemination of information between the various parties and, particularly, into the public domain via publication and particularly consultation has been poor. In one particular instance, the actions of Lancashire County Council might best be described as obstinately obstructive.

**Applicability of the Off-Site Emergency Plans**

In the United Kingdom nuclear facilities are licensed in accord with the Nuclear Installations Act 1965. Essentially, this Act requires that all aspects of operation of the plant, including abnormal operation, shall not result in health injury to any member of the public and this is interpreted by the licensing authority via the safety composite of *acceptable risk of accident* and *tolerability of consequences*. Within the definition of foreseeable incidents, the nuclear plant operator is able distinguish, so it is claimed, between those incidents that have such a low probability of occurrence that the consequences do not have to be considered (ie the consequences could be very severe and intolerable because the probability of occurrence is so remote) and those incidents which could occur for which the consequences must be tolerable (that is intolerable consequence incidents are engineered out of the system).

This somewhat dubious logic leads to a situation where only 'manageable' incidents are considered to be credible.

In effect, the local authority off-site emergency plans are geared to respond to incidents of manageable dimensions because these are only those that are reasonably foreseeable by the operator. Off-site emergency plans set against such manageable accidents are not, it might be argued, proven to be capable against incidents of greater severity and consequence. Such limited emergency response planning has failed in the past and occurrences of catastrophic events are not determined solely by probabilistic grounds – for example, Piper Alpha, Chernobyl and the Titanic.

**Extendibility and Terrorist Attack**

In the past, although some UK nuclear plants have been subject to mock attack exercises nothing on their vulnerability and/or performance has been published. Recently (May 2002), however, Bradwell nuclear power station was subject to some form of trial which involved the local authority emergency planning resource and which must have involved the central government Department of Trade's Office for Civil Nuclear Security (OCNS).[10]

Apparently (because nothing is publicly available), OCNS has evolved a new procedure to assess security threats which are to be incorporated into a Design Basis Threat document which is to be the key planning aid for the plant operators. The DBT will provide intelligence about the motives, intentions and capabilities of potential adversaries against which the plant operator is to 'beef-up' the plant management, contingency planning and physical security measures.[34,35] Once all of this is in place, the Director of the OCNS will evaluate the robustness of Britain's individual nuclear plants, making this publicly available in its first annual report.[36]

At governmental level there is the recently formed Cabinet sub-committee referred to as the Chemical, Biological, Radiological and Nuclear (CBRN). The role of CBRN is to review the contingency arrangements in place to protect against terrorist attack, although its findings are classified restricted and above, and nothing is publicly available on its membership and how and to whom it communicates its recommendations.

Like many other nuclear countries, Britain has been jarred into action by the events of 11th September. New committees have been formed, assessments are being made and there is now, via REPPIR, a real opportunity to put in place, resources permitting, effective emergency planning and consequence management measures.[37] It is quite clear from recent government statements and publicly released statements (sometimes hurriedly withdrawn) that central government agencies are planning to respond to terrorist acts that could have catastrophic consequences and that nuclear power plants are acknowledged to be potential targets. Yet, at the local authority level, there is no requirement to plan specifically for terrorist acts nor for the scale of damage severity and consequences that such actions might bring about.

## Notes & References

1 The Local authority has to have a written plan in place within six months of being notified by the HSE and it may apply for an extension to complete its Off Site Plan. The current (October 2002) dates of notification for UK nuclear installations are as follows:

| PLANT | DPZ km | DATE | COMMENT |
|---|---|---|---|
| HARWELL | 1.2 | 4 July 2002 | |
| WINFRITH | | | |
| CAPENHURST | 1 | 4 July 2002 | |
| SPRINGFIELDS | 1.2 | 3 July 2002 | |
| WINDSCALE (UKAEA) | 2 | 2 July 2002 | |
| DRIGG | | | |
| SIZEWELL B PWR | 2.4 | 3 July 2002 | |
| URENCO CAPENHURST | 1 | 4 July 2002 | |
| SELLAFIELD | 2 | 3 July 2002 | |
| TORNESS AGR | 3 | 19 June 2002 | |
| DUNGENESS AGR | 2.4 | 23 May 2002 | |
| HUNTERSTON AGR | 2.4 | 30 May 2002 | |
| HEYSHAM AGR | 1 | 30 May 2002 | |
| HARTLEPOOL AGR | 1 | 28 May 2002 | |
| HINKLEY POINT AGR | 3.5 | 27 May 2002 | |
| DUNGENESS MAGNOX | 2.4 | 23 May 2002 | |
| HINKLEY POINT MAGNOX | 3.3 | 27 May 2002 | |
| HUNTERSTON MAGNOX | | | closed down & defuelled |
| TRANSFYNYDD MAGNOX | 1.3 | 19 June 2002 | closed down & defuelled |
| CHAPELCROSS MAGNOX | 2 | 19 June 2002 | |
| CALDER HALL MAGNOX | | | |
| BRADWELL MAGNOX | 2.4 | 14 June 2002 | |
| SIZEWELL MAGNOX | 2.4 | 14 June 2002 | |
| OLDBURY MAGNOX | 1 | 19 June 2002 | |
| WYLFA MAGNOX | 1.6 | 4 July 2002 | |
| BERKELEY MAGNOX | | | closed down & defuelled & part dismantled |
| DOUNREAY | | | |
| HMS VULCAN | | | |
| ALDERMASTON | | | |
| BURGHFIELD | | | |
| DEVONPORT | | | |
| FASLANE | | | |
| ROSYTH | | | |
| COULPORT | | | |
| RR DERBY | | | |
| AMERSHAM | | | |
| CULHAM JET | | | |
| CULHAM WASTE | | | |

2 These regulations supersede the requirements of the *Ionising Radiations Regulations* that place a duty on the nuclear operator to assess the nature and extent of the hazard and the radiation exposure and health and safety relating thereto. *Regulation 18* provides opportunity for exemption although it is believed that the Secretary of State for Defence will not seek this.

3 The operator's report of Assessment has to provide sufficient information on all reasonably foreseeable radiological incidents, including for the nature, rapidity and magnitude of any projected radioactive release.

4 HSE Guidance to REPPIR, 2001

5 REPPIR adopt many of the emergency planning principles of the Control of Major Accident Hazards Regulations 1999 (COMAH) and formalise into regulations previous emergency planning arrangements with local authorities that have been in place around nuclear licensed premises for many years, nor does REPPIR replace existing nuclear site licence conditions but operators of licensed sites who comply with those conditions will satisfy equivalent provisions in REPPIR.

6 *Suffolk County Council, 'Sizewell Nuclear Power Stations – Offsite Emergency Plan Summary'*, 2pp, available from the Emergency Plans Team, Suffolk County Council, undated

7 Following defuelling and the removal of certain components it is planned to de-staff the closed down power stations and to monitor these remotely with just occasional inspections by personnel – this minimal attendance is referred to as institutional care.

8 In may not be the local authority Emergency Planning Officer who actually takes charge and implements the off-site plan, this may be passed to the Senior Executive of the authority acting through an executive committee structure.

9 The last three stable categories, *F*, *G* and *H* are night conditions, whereas REPPIR recommends that the most stable category to be considered should be no greater than *D* which is defined as neutral, typically an overcast day or night with wind speed about 5m/s

10 *Bradwell Level 3 Exercise* of 10 May 2002, BNFL Emergency Planning Services, Final report, September 2002

11 See Regulation 2(1) and Schedule 1 for a fuller definition – 5mSv is 5 times the present annual radiation dose exposure limit of 1mSv for members of public.

12 Some of these hazards are exempted from REPPIR, for example Regulation 3(4) exempts Type B fuel flasks from REPPIR on the basis, it is assumed, that these flask will not be breached in any reasonably foreseeable circumstances, although here we are considering exceptional circumstances such as a rail tunnel fire and/or a terrorist attack; accidents and incidents arising in the transportation phase are required to be covered by the Carrier's Plan which has the primary function of stopping the release from its containment but there is a requirement for the carrier to consult with national representatives of the local authority rather than with each local authority. Irrespective of these exemptions, should such an incident occur then, undoubtedly, the local authority would be expected to respond and deploy an adapted version of its REPPIR Off-Site Emergency Plan

13 The analysis assumes 100% release of all noble gases; 10% of the relatively volatile caesium, ruthenium and tellurium; and 1% of all other radionuclides. These are relatively conservative release fractions compared to the recommended fractions for a severe reactor accident (Nuclear Regulatory Commission – US NRC)

14 Large & Associates, *Import/Export of Irradiated Fuel and Radioactive Waste to and from the United Kingdom*, R1924, 1993 – see also Nelsen J M et al *Thermal Response of the Modified HNPF Spent Nuclear Fuel Shipping Cask when subjected to a Torch Fire Environment*, SAND84-1556 TTC-0501, 1984 Rack H J et al *Postmortem Metallurgical Examination of a Fire Exposed Spent Fuel Shipping Cask*, SAND79-1424, TTC-0018, 1980

15 Population densities are taken uniform distributions of 10,000 to 4,200 per $km^2$ for urban areas and 250 to 300 per $km^2$ for rural areas.

16 National Radiological Protection Board, which acts as the advisor to Government. Recently the NRPB Working Group on Stable Iodine Prophylaxis reported its concern on the vulnerability of young children following an accidental release of radioiodine. This is because young children's thyroids are more radiosensitive. The Working Group's recommendations suggested that the prime focus of emergency planning should be the protection of neonates, children under 10 years, and pregnant and nursing women and for this the ERL Upper Limit should be reduced to 100mGy (~from 300mSv to 100mSv) since the present upper ERL is considered too high to provide adequate protection to the young. In addition the World Health Organisation has recommended reducing the lower ERL to 10mGy (from 30mSv to 10mSv).

17 Regulation 15 of REPPIR permits the disapplication of dose limits once a Radiation Emergency has been declared, although the disapplication is conditional on the state of the emergency.

18 These are the ERL thresholds set down by the NRPB. The lower ERL is the dose level below which the countermeasure should not be introduced because it would be very unlikely to be justified to do so. If estimated averted doses exceed the lower ERL, implementation of the countermeasure should be <u>considered</u> but is not essential. The upper ERL is the dose level at which <u>every effort</u> to be made to <u>introduce</u> the countermeasure unless it would clearly contravene the principles of *justification* and *optimisation* to do so. The ERL principles are intended to be used as one of the major inputs to the establishment of emergency plans and as guidance for actions when an accidental release or other emergency has actually occurred.

19 In an emergency, the NRPB would send monitoring teams to the affected area to measure dose rates and surface contamination using hand-held instruments from which the NRPB would assess, by referring to analysts at its Chiltern headquarters, the exposure levels and forecasts for the ERL systems of triggering countermeasures. The basic principles recommended by the Board for the protection of the public should an accident occur are that countermeasures should be introduced if they are expected to achieve more good than harm, the quantitative criteria used for the introduction and withdrawal of countermeasures should be such that protection of the public is optimised, and that serious deterministic health effects should be avoided by introducing countermeasures to keep doses to individuals to

levels below the thresholds for these effects. These principles apply to all the countermeasures which could be taken to protect the public, and in particular to sheltering, evacuation, the administration of tablets containing stable iodine, the imposition of restrictions on the consumption of food and water, and relocation.

The NRPB considers that, when emergency plans are prepared for any given nuclear installation or potential accident, account should be taken of, inter alia, the nature and magnitude of possible doses and the practicability of implementing each countermeasure, or combination of countermeasures, in order to select specific intervention levels which could be used in most circumstances. These intervention levels are expected to be between the lower and upper ERLs. However, the flexibility to take actions appropriate to the conditions at the time of an accident should be retained because there could be occasions when a countermeasure, even though desirable under most circumstances, is impractical. It is also necessary to check that total doses to individuals will be below the thresholds at which deterministic effects may occur because the ERLs are in terms of averted dose.

[20] For irradiated fuel in transit the radioiodine fission product level will be at an insignificant level because irradiated fuel is normally retained in the power station storage ponds for a period over which the significant iodine isotope, I-131, has naturally decayed – usually at least six months for Magnox fuel.

[21] If the number of derailments are known on a *post priori* basis, say for the annual freight train route miles travelled on the rail network and the linear length of tunnels known in proportion to the total track miles, then for a known ratio of irradiated fuel transit to total freight miles per year the probability of a derailment of an irradiated fuel train within the confines of a tunnel can be forecast. For example, to work out the probability of an irradiated fuel train derailing and impacting with a hard surface (bridge, tunnels and other 'hard' structures), for the irradiated fuel traffic projected for a single nuclear power station, the rate of bogie (flatrols) movements per year on the rail network is about $2.5.10^{-7}$ per bogie per mile, giving about $1.10^{-3}$ for the single nuclear plant and the presence of solid impact objects is about $10^{-2}$ for a typical irradiated fuel transport route from the station (here taken to be Sizewell) to Sellafield, and in account of other attenuating factors to cover variables such as impact speed, energy partition between the fuel flask and the impacting object, say about 0,075 in all, the final risk estimate giving the chance of a serious impact after derailment at speed is about $7.5.10^{-7}$ per year.

[22] Ideally, the iodine prophylaxis should be initiated prior to the arrival of the source of exposure – the radioactive cloud – so that the thyroid is swamped with the administered iodine thus minimising competition with absorption of the unstable radioactive iodine. Obviously, in rapid release scenarios it may not be possible to administer the iodine prophylaxis sufficiently ahead of the arrival of the radioactive source.

[23] *Reg 17* and *Schedule 10* require the local authority to provide information to members of the public in the event of a radiation emergency and as it develops, detailing where possible the extent and probable development of the radioactive release.

[24] Letter from the DTI Nuclear Industries Division to NELPG members, 11 March 2002

[25] Emergency Preparedness of the National Health Service, National Audit Office, November 2002

[26] Seventh Special Report of the House of Commons Defence Committee, *Defence and Security in the UK*, October 2002

[27] The ASA is the national organisation representing all of the National Health Ambulance Trusts.

[28] In fact, the Police Forces approached directly would not give any information on a dose limitation system, the extent of the training in radiological management and the issue and use of personal radiation monitoring equipment, although the response seemed more of surprise and ignorance of the need to have such personal protection systems in place.

[29] Typically, personal monitoring film badge dosimetry requires replacement every three months.

[30] Note for the Record, Meeting to Discuss Implications of UK Working Group Recommendations on Stable Iodine Prophylaxis**, 24** May, 2002 during which the application of putting into place the recommended revised ERL for thyroid uptake included *"For some sites, detailed emergency planning for stable iodine prophylaxis is based on NRPB's upper ERL. However, the extent of the detailed emergency planning zones (DEPZs) is set well beyond the extent required for distribution of stable iodine based on the upper ERL. With the possible exception of two sites, adoption of a lower value for the detailed planning basis, even down to the level of the current lower ERL, would not result in an extension of the DEPZ. For two sites, a very small extension of the DEPZ might be required if NRPB's lower ERL for stable iodine prophylaxis were adopted as the detailed planning basis. . . . For all sites, the implications of NRPB reducing the lower ERL for stable iodine prophylaxis are potentially profound. Such a change would require an extension of all current DEPZs, and, consequently, an increase in the size of population requiring distribution. For one MoD site, a reduction to 10mGy thyroid dose would result in tens of thousands more people included within the DEPZ. . . .It was noted that a revision to NRPB's ERLs for stable iodine prophylaxis would also require NRPB to review its other ERLs, or, at least, the ERLs for sheltering as these had been deliberately set to coincide with the ERLs for stable iodine. Industry representatives warned that any changes to other ERLs could have a substantial impact on emergency plans, and that a change to the lower ERL for evacuation might have even more wide ranging impact, eg on safety cases.".*

[31] For example, three local groups were asked if they had been approached by their local authority. CORE (Cumbrians Oppose to Radioactivity at Sellafield), Stop Hinkley and Shut Down Sizewell had not been contacted by their respective local authority over REPPIR.

[32] Report of Assessment of the Hazard Identification and Risk Evaluation for the Southampton Z Berth, Unclassified, 5 February 2002 but released 15 November 2002.

[33] Letter from MoD Warship Support Agency, WSA Sec/038/0076/7327, 19 November 2002

[34] The approach in the United States is quite different. For other Design Basis Threats (DBTs) the US Nuclear Regulatory Commission requires nuclear plant operators to submit to *force-on-force* trials simulating intentional malicious actions. Since 1991 the NRC has conducted 91 trials or *Operational Safeguards Response Evaluation* tests, of which about 45% of the tested nuclear plants failed. Most disturbing is that three

plants tested shortly before 11th September, Farley, Oyster Creek and Vermont Yankee, were the worst on record. In another assessment, the NRC notes that between 15 to 20% of US nuclear plants would sustain safety critical levels of damage from vehicle bombs accessing close to the supervised boundary of the plant.

35 Lyman E, *Terrorism Threat and Nuclear Power: Recent Developments and Lessons to be Learned,* Rethinking Nuclear Energy and Democracy after 09/11, Int Symp, PSR/IPPNW Switzerland, Basel April 2002)

36 The DTI OCNS first report has now been published but it contains no details whatsoever about the performance of the individual nuclear power plants, although it notes that it, itself, is experiencing staffing difficulties that does not permit it to carry out its function completely.

37 There is considerable confusion, or so it seems, relating to the emergency limits for radiation exposure for individuals expected to support the local authority off-site emergency plan. For example, local authority off-site plans assume that the three emergency services will attend without restriction. Of these, the firefighters have their own nationally agreed incident exposure limits (50mSv and 100mSv for lifesaving), the Ambulance Service Association (representing all 35 UK NHS ambulance services) has a *'zero tolerance'* of radiation exposure for its crews and paramedics, and the police forces do not provide specific training and individual officers are not issued with any means of personal dosimetry – only the firefighters seem to be aware of the need to have a competent person overseeing the radiation exposure of individual firefighters and crews. The incredible situation of having a number of competent persons, each permitting different exposures is possible under the *Regulations*.

The differences in the dose limitation systems (where such exist) could result in non-attendance of the ambulance crews, definitely staged withdrawal of firefighters at their own preset limits, that is well before local authority employees reach the HSE's recommended radiation exposure limits (100mSv and 250mSv for lifesaving), leaving just the police alone to lead the countermeasures without the support of their emergency services colleagues.

On its part, the HSE is presently recommending emergency dose limits of 100 and 250mSv, the latter for life saving, for those individuals participating in the off-site plan but this seems to give no account of the high risk nature of the employment of firefighters and police officers (ie in account of the total risk including that encountered in the course of non-nuclear activities) and the fact that the majority of local authorities could not be expected to train and equip each of their employees participating in the emergency with real time personal dosimetry equipment.