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Nuclear Terrorism: The Risks and Realities in Britain

Dr. Frank Barnaby

February 2003

Introduction

The terrorist attacks on New York and Washington on 11 September brought home the willingness of a new breed of terrorists, now called the ‘new terrorists’, to kill, by terrorism, as many people as possible and cause the maximum amount of social and economic disruption. To discuss future terrorism it is useful and important to distinguish between the ‘old’ terrorists, likely to continue with ‘business as usual’, using conventional weapons to ‘kill one and frighten thousands’, and the ‘new terrorists’, aiming to ‘kill thousands to frighten the hemisphere’ with weapons of mass destruction.

Different types of ‘old’ terrorism can be identified: political terrorism, usually with separatist or nationalist aims; terrorism by far right- and left-wing political groups; terrorism by single-issue groups, like right-to-lifers and radical environmentalists; and terrorism by an individual.

Current trends suggest that political terrorism with separatist or nationalist aims is likely to decrease in the future and terrorism by single-issue groups is likely to remain roughly constant. But the other types of terrorism are likely to increase.

The new terrorism and weapons of mass destruction

Terrorist actions by the ‘new’ terrorists - religious fundamentalists, particularly Islamic Fundamentalist groups and American Christian white supremacists – are likely to become increasingly frequent and violent. Whereas secular terrorists are likely to exercise constraint, and to avoid killing many when killing a few suits their purposes, religious fundamentalists are unlikely to feel any moral constraint about killing very large numbers of people.

In fact, mass killing by weapons of mass destruction may fit well into the Armageddon and apocalyptic visions of some religious groups, some of which believe that they are under divine instruction to maximise killing and destruction. The likelihood that terrorist violence by fundamentalist groups will escalate to indiscriminate mass killing is the greatest future terrorist risk, the main consequence of increasing religious terror and decreasing radical political terror. The best way the new terrorists can achieve their objective is to use a weapon of mass destruction. There is, therefore, clearly a danger, some would say inevitability, that new terrorists will acquire, or develop and fabricate, and use weapons of mass destruction – chemical, biological or nuclear.

Recent experience - for example, the use of nerve agents by the AUM group in Tokyo and the use of anthrax in the USA - shows that biological and chemical weapons are unpredictable and difficult to use effectively (i.e. to give a large number of casualties). Effective dispersal of both biological and chemical weapons is very difficult. This suggests that chemical and biological weapons will not well serve the purposes of the new terrorists.

To fulfil their aims, therefore, future new terrorists are more likely to make nuclear attacks than biological or chemical ones. Nuclear attacks are not only more likely to succeed but their Armageddon nature is likely to appeal to fundamentalists.

Nuclear terrorism

There are number of nuclear terrorist activities that a terrorist group may become involved in:

- stealing or otherwise acquiring a nuclear weapon from the arsenal of a nuclear-weapon power and detonating it;
- stealing or otherwise acquiring fissile material and fabricating and detonating a primitive nuclear explosive;
- attacking a nuclear-power station reactor to spread radioactivity far and wide;
- attacking the high-level radioactive waste tanks at reprocessing plants to spread the radioactivity in them;
- attacking a plutonium store to spread the plutonium in it; and
- attacking, sabotaging or hijacking a transporter of nuclear weapons or nuclear materials.
- making and detonating a radiological weapon, to spread radioactive material;

All of these types of nuclear terrorism have the potential to cause very large, large, or quite large, numbers of deaths. Given the potential serious consequences of a nuclear terrorist attack, policy makers have to make a judgement about the probability of it happening, a very difficult judgement.

Of the various types of nuclear terrorist attack, nuclear terrorists would probably prefer to set off a nuclear explosive, perhaps using a stolen nuclear weapon or, more likely, using a nuclear explosive fabricated by them from acquired fissile material. The Armageddon and Apocalyptic symbolism of a nuclear explosion would particularly attract religious fundamentalist terrorist groups.

Terrorist use of a primitive nuclear weapon

Terrorists would be satisfied with a nuclear explosive device that is far less sophisticated than the types of nuclear weapons demanded by the military. Whereas the military nuclear weapons with predictable explosive yields and very high reliability, most terrorists would be satisfied with a relatively primitive nuclear explosive.

Terrorist could make a nuclear explosive from highly enriched uranium or plutonium. The simplest nuclear explosive uses the 'gun technique' in which a mass of enriched uranium less than the critical mass is fired, down a gun barrel, for example, into another less-than-critical mass of uranium. The sum of the two masses is greater than critical.

The gun technique cannot be used to assemble a super-critical mass of plutonium in a nuclear explosive device; a technique called implosion must be used. The implosion technique can, however, be used to assemble a super-critical mass of highly enriched uranium. In a nuclear explosive using the implosion design, a sphere of plutonium or highly enriched uranium is surrounded by conventional high explosives.

When exploded, the high explosive uniformly compresses the sphere of fissile material. The compression reduces the volume of the sphere of fissile material in the core and increases its density. The critical mass is inversely proportional to the square of the density. The original less-than-critical mass of fissile material will, after compression, become super-critical, and a fission chain reaction and nuclear explosion will take place.

Two or three people with appropriate skills could design and fabricate a crude nuclear explosive. The size of the nuclear explosion from such a crude nuclear device is impossible to predict. But even if it were only equivalent to the explosion of a few tens of tonnes of TNT it would completely devastate the centre of a large city. Such a device would, however, have a strong chance of exploding with an explosive power of at least a hundred tonnes of TNT. Even one thousand tonnes or more equivalent is possible, but unlikely. The effects of a nuclear explosion equivalent to that of 100 and 1,000 tonnes of TNT are described in the Appendix.

It is a sobering fact that the fabrication of a primitive nuclear explosive using plutonium or highly-enriched uranium would require no greater skill than that required for the production and use of the nerve agent produced by the AUM group and set off in the Tokyo underground.

Terrorist attack on a nuclear-power station

Instead of exploding a nuclear weapon, a terrorist group may decide to attack a nuclear facility. It is generally recognised that a terrorist group with significant resources could attack and damage nuclear-power plants. There is argument, however, about how much damage and how many people would be harmed by such an attack. It is probably true that attacks on nuclear-power plants that could do a great deal of damage and cause many fatalities have a relatively small chance of success. But many believe that the damage caused by and the number of people killed by a successful terrorist attack on a nuclear-power plant could be so catastrophic that even a small risk of such an attack is not acceptable.

There are two potential targets in a nuclear-power station for a terrorist attack: the reactor itself and the ponds storing the spent fuel removed from the reactor. An attack on the reactor could cause the core to go super-critical (as happened during the 1986 accident at the Chernobyl reactor) or cause a loss of the coolant that removes heat from the core of the reactor (as happened during the reactor accident at Three Mile Island.

Spent fuel elements are normally kept in storage ponds for five or ten years under three or so metres of water before they are either finally disposed of in a geological repository or sent to a reprocessing plant where the plutonium inevitably produced in the fuel elements is chemically separated from unused uranium and fission products in the fuel elements. The ponds are normally built close to the reactor building. The buildings containing the spent fuel ponds are less well protected than the reactor and are, therefore, more attractive targets than the reactor building.

Terrorists could target a reactor or spent fuel pond by: using a truck carrying high explosives and exploding it near a critical part of the target; exploding high explosives carried in a light aircraft near a critical part of the target; crashing a high-jacked commercial airliner into the reactor building or spent-fuel pond; attacking the power station with small arms, artillery or missiles and occupying it; or by attacking the power lines carrying electricity into the plant. Alternatively, a terrorist group may infiltrate some of its members, or sympathisers, into the plant to sabotage it from inside. A saboteur may attack, for example, the systems cooling the reactor core or drain water from the cooling pond. This could cause the temperature of the reactor core to rise, resulting in a release of radioactivity form the core, or cause the temperature of the spent fuel rods to rise, again resulting in a release of radioactivity.

Perhaps the most likely scenario of a terrorist attack, by a sophisticated and ruthless group, on a nuclear-power station is sabotage from within the station. The saboteurs would aim to create a criticality or loss-of-coolant accident or both leading to a massive release of radioactivity from the reactor core or the spent fuel elements. Another possibility is to crash a commercial airliner into the reactor building or spent-fuel pond.

Terrorist attacks on high-level radioactive liquid waste tanks or plutonium stores at Sellafield

It is hard to think of a nuclear terrorist attack which could, at least in theory, be more catastrophic than a successful attack on either the tanks at Sellafield that contain the liquid fission products separated from spent reactor fuel elements by the two reprocessing plants or on the stores holding the plutonium separated by the reprocessing plants.

The high-level radioactive liquid waste tanks

A major concern after the September 11, 2001 terrorist attacks in New York and Washington is an attack on nuclear facilities at Sellafield in which a large commercial aircraft, such as a Boeing 747 carrying a full load of fuel, is dived from a high altitude into the liquid high-level radioactive waste (HLW) tanks or the plutonium store. A fully laden jumbo-jet travelling at between 200 and 300 metres a second would have a very large momentum and the crash would have a huge impact. In addition, the aircraft may be carrying about 150 tonnes of aviation fuel and the crash would create a very fierce fire.

Highly radioactive liquid waste, fission products arising from the operations of the two reprocessing plants at Sellafield, is stored in 21 water-cooled tanks (1). Normally, at any one time, fourteen of these tanks are full of liquid fission products; the other seven are kept empty in case it is necessary to empty some of the other tanks. Without cooling, the heat produced by the radioactive decay of the isotopes in the HLW would cause the liquid to boil and the tanks to explode. The total volume of liquid HLW stored at Sellafield is about 1,575 cubic metres.

So far as the contamination of the human environment and damage to human health are concerned, the most important radioisotope in the HLW tanks at Sellafield is caesium-137 (Cs-137). Cs-137 decays radioactively by emitting beta particles (electrons) and gamma rays. The gamma rays, with an energy of 662,000 electron volts (662 kev), are very penetrating and particularly hazardous to people exposed to it.

The contamination of a large area with Cs-137.

Any of the 21 HLW tanks at Sellafield that survived the initial impact of the terrorist attack considered here are likely to dry out because the impact will cut off the cooling system. Cs-137 is volatile and the bulk of it will escape into the atmosphere over, say, a two-day period. It would not be possible to establish emergency cooling for weeks because of the high level of radioactivity in the area.

In the first minute or so after the accident, the fire caused by burning aviation fuel is likely to produce a fire-ball rising to an altitude of up to between one and two kilometres. After the first minute or so, radioactivity will continue to be released but will not rise more than a few metres into the atmosphere.

Based on figures published by NIREX in 1998 inventory, the total amount of Cs-137 in the HLW tanks is probably about 6.2 million TBq. This amount of Cs-137 weighs about 1,980 kilograms. It is reasonable to assume after an airliner crash of the type considered here roughly a third of the Cs-137, or about 2 million TBq, could go up in the fireball and be spread by the wind over a large area of Britain. Radioactivity will reach Ireland and parts of Europe, in amounts that will depend on the strength and direction of the wind. In addition, roughly a half a million TBq will probably be spread over a much smaller area around Sellafield.

It is instructive to compare the radioactive contamination potentially caused by a terrorist attack on Sellafield with that caused by the reactor accident at Chernobyl on 26 April 1986. The Chernobyl accident released about 0.08 million TBq of Cs-137 or 25 kilograms of Cs-137, about 4 per cent of the 2 million TBq that may be released by a terrorist attack on the HLW tanks at Sellafield (2).

According to figures given by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the exposure of people to the radiation emitted by the Cs-137 released during the Chernobyl accident produced a worldwide collective radiation dose of 600,000 person-sieverts over a period of 50 years (3).

The International Commission on Radiological Protection (ICRP) estimates that the risk of a fatal cancer per unit radiation dose is 0.05 fatal cancers per person-Sv. The UNSCEAR figure suggests that the number of fatal cancers produced by the Chernobyl accident is 30,000.
Scaling up the calculated Sellafield release to the Chernobyl accident suggests that a terrorist attack on the HLW tanks could result in a worldwide collective dose of about 22 million person-sieverts, resulting in about 750,000 fatal cancers. Depending on the strength and direction of the winds at the time of the release of the radioactivity, these deaths will occur in the United Kingdom, Ireland and parts of Europe and perhaps even further afield.

If the terrorist attack on the HLW tanks releases more radioactivity than is assumed above then the number of fatal cancers will be proportionally larger. In the worst case, if all the Cs-137 is released, the number people getting fatal cancers could reach a total of about 2.25 million.

The plutonium stores

The two plutonium stores at Sellafield contains the plutonium (Pu) separated from spent nuclear-power reactor fuel elements in the two Sellafield reprocessing plants. Currently, the store contains about 71 tonnes of Pu, mainly from spent fuel from British Magnox reactors, in the form of plutonium dioxide (PuO_2).

About 60 tonnes of this Pu is British owned; the remainder is foreign owned. About 5 tonnes of the British Pu comes from the reprocessing spent fuel from Advanced Gas-Cooled Reactors (AGRs); the other 55 tonnes of British Pu is from Magnox reactors (4).

A terrorist attack on a Pu store could contaminate the environment with Pu. Pu creates a different hazard to human health than Cs-137. Cs-137 creates an external hazard to humans. If it is outside the body, its energetic gamma radiation can penetrate into the body, damaging the cells in it. Pu isotopes, however, do not typically emit energetic gamma rays but emit alpha particles (nuclei of helium atoms) instead.

If Pu is inhaled or ingested, these alpha particles can be particularly damaging to the cells of the body, producing an internal rather than an external hazard. When outside the body, Pu does not present a significant hazard but Pu is particularly toxic when inhaled into the lungs. The main task after a release of Pu into the human environment is the evacuation and decontamination of land contaminated.

It is reasonable to assume that, on average, the inhalation of 0.153 mg of Pu originating from a Sellafield Pu store has a very high probability of producing a fatal cancer. A PuO_2 particle containing 0.153 mg of Pu would have a diameter of about 300 microns (1 micron is 1/1,000,000 metre or 1/10,000 centimetres.) It would not be possible to inhale such particles deep into the lung, where the lung tissue can absorb them. Any particle bigger than about 3 microns is not inhaled and is said to be not respirable. A 3-micron PuO_2 particle has a mass of 1.55E-07 mg. To inhale a total of 0.153 mg, it would be necessary to inhale about 900,000 3-micron PuO_2 particles. This is a lot of particles.

But a very large number of respirable particles would be produced if a fire disperses PuO_2. If, for example, a high-temperature fire disperses 1 kilogram of PuO_2, about 6.5 trillion (million million) of them will be produced. At least a half of them are likely to be respirable.

An averagely active person breathes about 1.5 cubic metres of air a minute (5). Assume that 2 kilograms of PuO_2 are burnt in a fire and the 1-kilogram of respirable particles are uniformly dispersed through a cube of air, 500 metres on the side. The concentration of respirable Pu in the air is then 0.008 mg per cubic metre. One hundred people breathing this air for 1 hour would inhale 100 x 1.5 x 0.008 = 1.2 mg. This would be enough to produce about 8 fatal cancers in the group.

It must be emphasised that calculations of the number of fatal cancers caused by the inhalation of Pu after an explosion are, to say the least, highly speculative. The number of deaths will depend on a number of variables - including the number of people in the open, the length of time people remain in the open, the way that the cloud containing the Pu particles moves, the rate at which the particles fall out of the cloud, and so on. But it can be concluded that the dispersion of many kilograms of Pu is likely to lead eventually to a very large number of deaths from cancers caused by the inhalation of Pu.

Particles that have fallen to the ground are still a potential health hazard. If the particles are disturbed, or blown by the wind, they can become airborne again. The concentration of resuspended Pu particles will be much less than the original concentration of Pu particles in the cloud, but they will remain a health hazard until the area is decontaminated, a very time-consuming and costly operation.

The level of land contamination with Pu isotopes that would require decontamination (by, for example, the removal of top soil) depends on the circumstances. The UK National Radiological Protection Board (NRPB) recommends that land contaminated by more than about 1,000,000 Bq per square metre of relatively insoluble radioactive fine particles, like PuO_2, will require evacuation until it is decontaminated.

If evenly distributed, a kilogram of Pu in the Sellafield store will, on average, contaminate more than 300 square kilometres to the level at which the NRPB recommends evacuation. A terrorist attack on a Pu store at Sellafield could contaminate a huge area of land.

Terrorist use of a radiological weapon

The simplest and most primitive terrorist nuclear device is a radiological weapon or radiological dispersal device, commonly called a ‘dirty bomb’. A "dirty bomb" would consist of a conventional high explosive – for example, semtex, dynamite or TNT, and a quantity of a radioisotope.

The conventional high explosive is used to spread radioactive contamination. A radiological weapon is not a nuclear weapon (of the type described above) – it does not involve a nuclear explosion.

Any radioisotope could be used in a dirty bomb. But the most likely one to be used is one that is that is relatively easily available, has a relatively long half-life, and emits energetic gamma radiation. Suitable ones include caesium-137, cobalt-60, and iridium-192. Strontium-90, which emits electrons (beta particle) and is concentrated in bone, is also a possible candidate.

The detonation of a dirty bomb is unlikely to cause a significant number of casualties. Generally, the explosion of the conventional explosive would most likely cause any immediate deaths or serious injuries. The radioactive material in the bomb would be dispersed into the air but would be soon diluted to relatively low concentrations. If the bomb is exploded in a city, as it almost certainly would be, some people are likely to be exposed to a dose of radiation. But the dose is in most cases likely to be relatively small. A low-level exposure to radiation would slightly increase the long-term risk of cancer. The main potential impact of a dirty bomb is psychological – it would cause considerable fear, panic and social disruption, exactly the effects terrorists wish to achieve. The public fear of radiation is very great indeed, some say irrationally so.

The explosion of a dirty bomb could result in the contamination of an area of a city with radioactivity. The area would have to be evacuated and decontaminated. The degree of contamination would depend on the amount of high explosive used, the amount and type of radioisotope in the bomb, whether it was exploded inside a building or outside, and the weather conditions. Decontamination is likely to be very costly (costing millions of pounds) and take weeks or, most likely, many months to complete. Radioactive contamination is the most threatening aspect of a dirty bomb.

There are literally millions of radioactive sources used worldwide in medicine, industry and agriculture; many of them could be used to fabricate a dirty bomb. They are often not kept securely. The International Atomic Energy Agency (IAEA) recently secured a powerful cobalt-60 source abandoned in a former hospital. Soon afterwards in Uganda the IAEA secured a source that was stolen for illicit resale. And the IAEA is searching through remote areas of the Republic of Georgia to locate and recover a number of missing powerful strontium sources.

In the United States and Europe, where security is relatively strong, thousands of radioactive sources have been lost or stolen, their present whereabouts unknown. Clearly, the lack of security on radioactive materials around the world is a major cause for concern.

Measures to counter nuclear terrorism

To effectively counter nuclear terrorism it is important to prevent terrorists from acquiring fissile materials, plutonium and highly enriched uranium, to fabricate a primitive nuclear explosive and from acquiring significant quantities of radioisotopes, particularly caesium-137, strontium-90 and cobalt-60, to build a radiological weapon. The protection of these radioactive materials is clearly of the utmost importance.

Making existing nuclear-power reactors less vulnerable to terrorist attack is not very feasible although storage ponds for spent fuel elements could be more hardened. And greater care could be taken to vet staff to make it more difficult for a terrorist group to infiltrate people into a nuclear-power station.

The protection of a nuclear facility with, for example, fighter aircraft or surface-to-air missiles is, to say the least, not an easy task. If a terrorist group hijacks a commercial aircraft on a regular flight path that takes it close to, for example, the Sellafield establishment and dives it on to a target in the nuclear facility, the time available to make sure that the aircraft really is attacking the facility and then to scramble fighter aircraft or fire surface-to-air missiles is probably too short to make a successful interception.

Securing nuclear materials

What could be done is to improve the security of nuclear materials. But this is not an easy task – particularly in a democracy. The degree of security that can applied in, for example, a hospital using large radioactive sources for therapy or in an industrial establishment, using large radioactive sources for, for example, x-raying large structures, is obviously limited. But at the very least establishments using large radioactive sources should apply security measures such as keeping strict inventories, providing securely locked storage facilities and security guards.

Society may decide that the risk of terrorists acquiring and using a nuclear weapon, and the awesome consequences such use, are sufficiently awesome that some nuclear activities should be given up. An obvious example is the reprocessing of spent nuclear-power reactor fuel to separate the plutonium from it and the use of this plutonium to produce mixed-oxide (MOX) fuel for nuclear reactors.

MOX is a mixture of uranium oxide and plutonium oxide. The steps of chemically separating the plutonium oxide from uranium oxide, converting the oxide into plutonium metal, and assembling the metal or plutonium oxide together with conventional explosive to produce a nuclear explosion are not technologically demanding and do not require materials from specialist suppliers. The information required to carry out these operations is freely available in the open literature.

The fabrication of a primitive nuclear explosive using reactor-grade plutonium, obtained from MOX, would require no greater skill than that for the production of the nerve agent used by the AUM group on the Tokyo underground. None of the concepts involved in understanding how to separate the plutonium are difficult; a second-year undergraduate would be able to devise a suitable procedure by reading standard reference works, consulting the open literature in scientific journals and by searching the World Wide Web. A small number, three or so, of people with appropriate skills could separate the plutonium from MOX and design and fabricate a crude nuclear explosive. All the nuclear-physics data needed to design a crude nuclear explosive device are available in the open literature.

The storage and fabrication of MOX fuel assemblies, their transportation and storage at conventional nuclear-power stations on a scale currently envisaged by the nuclear industry will be extremely difficult to safeguard and protect. The risk of diversion or theft of MOX fuel terrorist groups is an alarming possibility.

The risk of theft of MOX is probably greatest when it is being transported. The international trade in MOX, involving the global transport of MOX increases this risk considerably.

The importance of good intelligence

The importance of effective intelligence in countering nuclear (or chemical or biological) terrorism cannot be over estimated. Monitoring the communications of terrorist groups – the activity known as signal intelligence (SIGINT) – has been crucial to this end. Modern terrorists can, however, take steps to protect their communication systems, including, for example, the use of encryption, frustrating the efforts of SIGINT.

The penetration of new terrorist groups by undercover intelligence agents or double agents (human intelligence or HUMINT) is, therefore, of critical importance. In fact, counter-terrorism is likely to succeed only if HUMINT can be made effective. This is why it is, to say the least, not going to be easy to defeat the new terrorists.

Experience shows that setting up effective intelligence activities against terrorist groups is extremely challenging. Rivalries between intelligence agencies within countries and lack of cooperation in intelligence matters between countries seriously reduce the effectiveness of intelligence. Effective and single leadership of national agencies and international cooperation between national agencies are the keys to good counter-terrorism intelligence.

The intelligence and security agencies, in their fight against the new terrorism, face an awesome task that will require the acquisition of any new technological developments relevant to counter-terrorist activities, a close study of new terrorist threats, and, perhaps most importantly, an imaginative approach to the issues.

Appendix

EFFECTS OF THE EXPLOSION OF A PRIMITIVE NUCLEAR EXPLOSIVE

A 100-tonne nuclear explosion

The largest conventional bombs used in warfare so far had explosive powers equivalent to about ten tonnes of TNT. The largest terrorist explosion so far has been equivalent to about two tonnes of TNT. A nuclear explosion equivalent to that of 100 tonnes of TNT in an urban area would be a catastrophic event, with which the emergency services would be unable to cope effectively.

Exploded on or near the ground, such a nuclear explosive would produce a crater, in dry soil or dry soft rock, about 30 metres across. For small nuclear explosions, with explosive powers less than a few kilotons, the lethal action of radiation covers a larger area than that affected by blast and heat. The area of lethal damage from the blast produced by a 100-tonne nuclear explosion would be roughly 0.4 square kilometres; the lethal area for heat would be about 0.1 square kilometres; and that for prompt radiation would be roughly 1.2 square kilometres.

Persons in the open within 600 metres of such an explosion would very probably be killed by the direct effects of radiation, blast, or heat (6). Many other deaths would occur, particularly from indirect blast effects from the collapse of buildings, from being thrown into objects or from falling debris. Heat and blast will cause fires, from broken gas pipes, petrol in cars, and so on. The area and extent of damage from fires may well exceed those from the direct effects of heat.

A nuclear explosion at or near ground level will produce a relatively large amount of early radioactive fall-out. Heat from fires will cause the radioactive particles to rise into the air; they will then be blown downwind, eventually falling to the ground under gravity at rates and distances depending on the velocity of the wind and the weather conditions.

The area significantly contaminated with radioactive fall-out will be uninhabitable until decontaminated. The area concerned may be many square kilometres and it is likely to take a long time to decontaminate it to a level sufficiently free of radioactivity to be acceptable to the public.

An explosion of this size, involving many hundreds of deaths and injuries, would paralyse the emergency services. They would find it difficult even to deal effectively with the dead. Many, if not most, of the seriously injured would die from lack of medical care. In the UK, for example, there are only a few hundred burn beds in the whole National Health Service. There would be considerable delays in releasing injured people trapped in buildings, for example.

And, even for those not trapped, it would take a significant time to get ambulances through to them and then to transport them to hospital. Therefore, a high proportion of the seriously injured would not get medical attention in time to save them. Experience shows that, when large explosions occur in an urban area, panic sets in which also affects the trained emergency personnel. This panic would be considerably exacerbated by the radioactive fall-out accompanying a nuclear explosion.

A 1000-tonne nuclear explosion

The British Cabinet Office has calculated the effects of a primitive nuclear explosive detonated at ground level in a typical city. The explosion was equivalent to that produced by 1,000 tonnes of TNT, a possible explosive yield from a crude nuclear explosive. Within one minute, people outdoors or near windows inside houses would be killed by thermal radiation (heat) up to a distance of 200 metres from the point of detonation. Within one minute, blast would kill people up to a distance of 800 metres, and initial nuclear radiation would kill people up to a distance of 1 kilometre.

People within two kilometres would be injured by blast and those within one kilometre would be injured by heat. Communications equipment would be damaged by the nuclear electromagnetic pulse up to a distance of about two kilometres and electronic equipment would be damaged or disrupted up to a distance of about ten kilometres, with severe consequences for fire services, police headquarters, and hospitals. The electromagnetic pulse would affect motor vehicles out to about ten kilometres.

Assuming a 24 kilometre per hour wind, ionising radiation levels from radioactive fallout within an area of about 15 square kilometres would be high enough to cause radiation sickness in the short term to those exposed in the open, and in some cases to those in buildings. This area would extend to some ten kilometres downwind and would have a maximum width of about two kilometres. Furthermore, radiation levels in an area of about 400 square kilometres would be such that certain counter-measures would have to be taken to protect people from the long-term effects of exposure to radiation - for example, fatal cancers. This area would extend some 80 kilometres downwind.

The most serious source of radioactive contamination from any crude nuclear explosive device is likely to arise from the dispersal of plutonium. If one kilogram of plutonium is uniformly distributed it will contaminate about 600 square kilometres to a level of one micro-curie per square metre, the maximum permissible level allowed for plutonium by international regulations. This means that a very large area will have to be evacuated and decontaminated, an expensive procedure that could take years.

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