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Background information on a current topic

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The dirty bomb: how serious a threat?

Possible repercussions of a radiological terrorist attack

1. Introduction

A “dirty bomb” is a conventional bomb spiked with radioactive material. The possibility of a terrorist strike making use of such a bomb has recently been hotly debated by experts. The media – especially in English-speaking countries – have brought the issue to the attention of the public at large. Yet, assessments of the likelihood of such an attack, and of its possible repercussions, are not concordant at all.

British and U.S. intelligence services seem to assume that a dirty bomb attack is to be expected soon. For them, the question is no longer whether it will occur, but when.[1]

Other experts think that the dirty bomb is not a particularly attractive option for terrorists, since the direct damage it causes is hardly greater than a conventional bomb, but is much more complicated and expensive to procure or produce. According to this reasoning a dirty bomb attack is not efficient enough – and therefore not likely to occur in the foreseeable future.[2]

[1] The Guardian, 18 June 2003: "MI5 says dirty bomb attack is inevitable".
[2] News Bureau, University of Illinois at Urbana-Champaign, 1 July 2002: "Danger of dirty bomb exaggerated".

The repercussions of a dirty bomb attack depend on a large number of parameters: the amount and type of radioactive material used in the bomb, the explosive charge, meteorological conditions – to name but a few. This means that the range of possible repercussions is very extensive.

Unfortunately a number of questionable "studies" presenting worst-case scenarios have been published on the Internet, claiming that a dirty bomb attack would cause the death by cancer of every tenth person in the most contaminated areas affected by the strike, i.e. in a big city fatalities would rise to thousands or even tens of thousands.[3] Such projections are unrealistic; they are based on the assumption that the authorities would take no measures to protect the population and decontaminate the affected area, and that the population would continue living there for decades as though nothing had happened.

It should be noted that there has as yet been no dirty bomb attack anywhere in the world. However, there was one serious threat: in November 1995 Chechen rebels informed several Russian television stations that a box containing radioactive material had been planted in Ismailovsky Park in Moscow. The relevant services were alerted and indeed found a small container filled with caesium in the place indicated. In this case the attack was not executed; the Chechen rebels probably wanted to prove their capacity to build such a bomb.

The SPIEZ LABORATORY has investigated the conditions and possible repercussions of a dirty bomb strike. The present publication summarises the results of these studies for the interested lay public. Needless to say, it contains no information that could be used to build or use a dirty bomb – the focus is entirely on the potential repercussions of the event.

2. What is a dirty bomb?

Experts distinguish between four nuclear terrorism scenarios:[4]

1. A home-made nuclear bomb ("DIY bomb“), called an Improvised Nuclear Device (IND) in the expert jargon;
2. A nuclear device that has been stolen or bought from a state that has nuclear weapons;
3. An attack against a nuclear installation, particularly a nuclear power plant or a shipment of nuclear material;
4. A radiological attack, i.e. the targeted dispersion of radioactive material.

A nuclear bomb in the strict sense of the word, i.e. the detonation of a bomb containing weapons-grade uranium or plutonium, is used only in scenarios one and two. Hiroshima and Nagasaki clearly demonstrated the destructive power of such a bomb. The dirty bomb on the other hand is not a nuclear device but a conventional bomb to which radioactive material has been added. Nuclear fission does not take place in such a bomb and the radioactive material has no bearing on its explosive power. The charge of a dirty bomb, i.e. the direct impact of the explosion, is in no way different from a conventional bomb with the same explosive charge. The same number of dead and injured and the same extent of damage to the infrastructure are to be expected.

However, radioactive material is released when a dirty bomb is detonated, causing radioactive contamination of the surroundings.[5] In the above list, a dirty bomb would therefore come under the heading of a radiological attack.

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[3] Testimony of Dr. Henry Kelly before the Senate Committee on Foreign Relations, 6 March 2002.

[4] Bernard Anet, Ernst Schmid, Christoph Wirz: Nuklearterrorismus: Eine Bedrohung für die Schweiz?, SPIEZ LABORATORY, ACLS Report 2000-03, 24. Oct. 2000.

[5] The dirty bomb is only one of several possible dispersion methods; a bomb is not absolutely necessary. Specialists speak of a radiological dispersion device (RDD), sometimes of an unconventional explosive and fire device with a radioactive charge.

3. How difficult is it to build a dirty bomb?

To build a dirty bomb, terrorists would first need to have access to explosives and the relevant expertise. The relatively large number of bomb attacks shows that this presents no major obstacle. The decisive factor, therefore, is access to a sufficient quantity of radioactive material. Sources of radioactive material for various applications are to be found in large numbers throughout the world – in Switzerland alone there are hundreds of them. However, not all of these sources would be suitable for use in a dirty bomb. Most are far too weak to cause extensive damage. Nonetheless we cannot completely rule out that terrorists could get their hands on the appropriate material and in sufficient quantities.

Manipulating a radioactive source of a certain strength requires knowledge of radioactive materials and radiation protection. Given that present-day terrorists are increasingly “suicide bombers” we may assume that safety considerations will not be their primary concern. A terrorist planning a suicide attack will hardly worry about long-term cancer risks.

To recapitulate: we may assume that terrorists would be able to manipulate radioactive material that is in their possession for use in a dirty bomb. They would also be able to use material they had procured in one country in another country.

Considering technical feasibility, we must therefore conclude that the construction of a dirty bomb is quite possible. In all cases it requires advanced know-how and planning, a very targeted approach, and considerable expenses. Nevertheless, there is no fundamental obstacle for terrorists to build a dirty bomb.

4. What are the repercussions when radioactive material is disseminated?

A dirty bomb attack involves the targeted release of radioactivity. What exactly does that mean? Radioactivity is a natural property of certain atomic nuclei. Putting things simply one could say that unstable atomic nuclei, so-called radionuclides, decay and are transformed into other atomic nuclei emitting radiation. The degree of instability of radionuclides varies greatly; it is expressed as "half-life". This designates the length of time needed for the disintegration of half of the decayable nucleus. An atom with a very unstable nucleus has a very short half-life – an extreme example is polonium-214, which has a half-life of only fractions of seconds. The material thus emits very strong radiation over a very short period of time. However, in practice a substance with such a short half-life cannot be set free since it exists but briefly. There are other radioactive atoms that have a half-life of several billion years, Uranium-238, for example, which may cause weak radioactive contamination over very long periods. This shows that only a few radionuclides are suitable for the construction of an effective dirty bomb.

Naturally a certain amount of radiation exists everywhere in the world, caused by the radioactive elements that are present in the natural environment, and by cosmic radiation that makes it to the earth. In very small doses – such as we are subject to in natural radiation – no harmful effects on living organisms have been detected. In greater doses radioactivity is harmful to all living organisms. The potential damage to health is proportional to the dose.

5. An aside: the radiological accident in Goiânia

On 13 September 1987 thieves made away with a piece of radiation therapy equipment they had found in an abandoned clinic in the Brazilian town of Goiânia, thinking the metal might be of some value. While taking the appliance apart, they opened the container with radioactive caesium-137. In the darkness, this powder gave off a blue phosphorescent glow that fascinated the men; they divided it up among themselves, took it home and distributed it among family and friends. Only on 29 September, after several people had come down with acute radiation syndrome and one person, who suspected that there might be a connection between the powder and the illnesses, had shown some of it to a physician, did the story come to light.

A number of people had been irradiated during this period, some of them in high doses; four people died, 28 suffered radiation burns. As a result 112,000 inhabitants of the town were tested for radioactive contamination; 249 were contaminated. The radioactive contamination had spread over several town districts – whole streets and squares were affected.

There were 85 contaminated houses; over 200 people had to be evacuated from the 41 most affected houses. Seven buildings were torn down. The topmost layer of soil was removed in certain gardens and public parks. In all, the authorities had to dispose of 3,500 m^3 of radioactive waste.

In spite of this massive decontamination effort, increased radiation levels were measured in some of the affected streets and squares 15 years later. This shows clearly that the accident had serious negative economic consequences for the town and the region. Sales of local products plummeted; GDP (gross domestic product) fell by around 20%. It took five years for the regional economy to recover.[6] The accident offers a telling illustration of the problems and hazards that such an event could provoke.

6. Would a dirty bomb attack imply acute radiation-induced health risks?

When penetrating the human body radioactive radiation loses a part of its energy. This energy is absorbed by the body and called the dose; the energy absorption per unit of time is called the dose equivalent. The unit habitually used to measure the dose equivalent is the Sievert or milliSievert per hour (Sv/h or mSv/h). In Switzerland the dose equivalent caused by natural radioactivity normally amounts to between 0.1 und 0.3 μSv/h (1 μSv read as 1 microSievert = 1 millionth of a Sievert), depending on whether one is in the Jura, in the Mittelland (Central Plateau) or in the Alps. The hazards of radioactive radiation depend very much on the dose and the dose equivalent. Total body irradiation (TBI) can lead to acute radiation sickness, especially when a high dose is accumulated over a short period of time. Table 1 lists the percentage of persons who will show symptoms of acute radiation sickness in the event of brief irradiation with the dose indicated, and how long it will take for these symptoms to appear.

Dose	< 0.25 Sv	1 Sv	2 Sv	6 Sv	8 Sv	> 30 Sv
Time		3 – 6 hrs	2 – 4 hrs	1 – 2 hrs	< 1 hr	Minutes
Nausea, vomiting	none	5%	50%	75% +	90% +	100%

Appearance of the first symptoms of acute radiation sickness

The four Goiânia fatalities had all carried the radioactive powder in their hands and had rubbed their bodies with it – probably because they were intrigued by its phosphorescence and saw it as a game. They also ate while doing these things, and thus swallowed radioactive dust. The 28 people who primarily suffered skin affections had also carried the powder, and rubbed themselves with it. With the dirty bomb this danger exists above all for the terrorists, who will have to manipulate the radioactive material. All the others – inhabitants, passers-by, members of the police, fire and emergency medical services – would only come into contact with a fraction of the amount of radioactive substances that caused the radiation damage in Goiânia.

An explosive blast sets off a chemical reaction which rapidly emits great quantities of heat. This produces a pressure wave which spreads in all directions. The heat can melt material; the pressure wave can break material. The same phenomena occur if a radioactive source is added to the explosive. Smaller particles would be carried further by the blast wind, contaminating a larger area. Depending on particle size, the radioactive substance might be inhaled by those present. Typically, radioactive contamination in an affected area decreases with the distance from ground zero. Contamination also decreases with time. First, weather conditions continuously remove radioactivity from the contaminated area; second, owing to the natural decay of the radionuclides. Natural decay alone causes a decrease of 50% within one half-life.

[6] Louis Charbonneau: A dirty bomb may not kill, but it sure would hurt, Reuters, 17 March 2003.

Mathematical models have shown that in the event of a dirty bomb attack we could expect dose equivalents of up to 10 mSv/h at the explosion site, where they are the highest, depending on assumptions made, like activity, meteorological conditions, amount of explosives. A person would have to spend one hundred hours in this core area to have a 5% likelihood of developing symptoms of acute radiation sickness. This makes it practically impossible for the affected inhabitants, services or passers-by to accumulate a radiation dose high enough for them to suffer radiation sickness or death.

The radioactivity emitted by a dirty bomb is therefore unlikely to present a serious health hazard. In spite of this, certain measures to ensure the safety of the affected population might prove necessary. Legal radiation thresholds are far lower than the threshold for acute radiation damage. All measures taken after a dirty bomb attack would thus have to focus exclusively on averting long-term radiation-induced damage, i.e. a possible rise in cancer and leukaemia risks.

7. Does the radiation emitted by a dirty bomb attack increase the risk of cancer?

The immediate repercussions of brief exposure to a high radiation dose are well known. On the other hand, the long-term effects of exposure – especially to a small dose - are much more difficult to evaluate. Exposure to smaller individual doses, but also permanent exposure to small doses may lead to increased risk of cancer and leukaemia in the long term. Moreover, it has been shown that people have different levels of tolerance to radiation and thus react somewhat differently to a given dose. This makes it very difficult to establish individual prognoses and evaluate the long-term risk of radiation exposure.

Radiation-induced cancer and leukaemia lie latent for a long period of time, often only to manifest themselves years or even decades after the event. Since the clinical symptoms of such a disease do not differ from those of spontaneous diseases, it is impossible to determine individually whether a case of cancer was induced by radiation or not. Only statistical methods enable us to establish a correlation between radioactivity and disease, when incidence is significantly higher in a sufficiently large group that suffered exposure than in a comparable but non-exposed group.

What has been proven scientifically is that the risk of disease increases with the dose. However, our current level of knowledge does not enable us to observe a correlation between cancer fatalities and a dirty bomb attack, since no significant statistical data would be available. In Switzerland, almost every third person suffers from cancer over his or her lifetime – one may hardly expect that a dirty bomb would generate a demonstrable increase in the number of cancer cases. The figure would probably oscillate within the normal, “natural” range.

On the other hand, this does not mean that the authorities would do nothing at all. In the event of a dirty bomb attack, orders would be given to implement measures in a limited area that were appropriate to the level of contamination.

8. What measures would be taken to protect the population?

In Switzerland, a decree on the Federal Emergency Organisation Radioactivity (VEOR) regulates what measures ought to be taken, and under what circumstances. In principle, depending on the degree of contamination, the following measures may be ordered to protect the population:

- Recommendation to shower and change their clothes to all persons who were outside during the attack;
- Temporary limits on time spent outside;
- Temporary stay in a basement or shelter;
- Limits on the consumption of certain agricultural products;
- Ban on harvesting, putting livestock out to pasture, hunting and fishing;
- Temporary evacuation or
- Definitive relocation of the affected population.

The mere fact of staying inside a house offers a safety factor of approximately 10, i.e. when the ambient dose rate measured outside is 1 mSv/h, it is 0.1 mSv/h inside. Evacuation can be ordered for a short period of time only, to allow the Civil Protection partner organisations to survey and decontaminate the affected area undisturbed. Evacuation is also a possibility when a building offers inadequate protection or conditions in it are too restrictive to be tolerable.

If it should prove impossible or too costly to decontaminate an area, the relocation of the population and the closing of the area may be considered. In the event of radioactive contamination these measures may reduce or even totally eliminate health hazards. The risk of radiation-induced cancer could be reduced to a degree that no demonstrable rise in cancer incidence would be expected. From the point of view of health hazards alone, the necessary measures could moreover be launched without undue haste, since a delay of several days would make hardly any difference. Possibly contamination would be so weak as to make all measures superfluous.

In the event of high-level contamination it might be necessary to decontaminate the affected persons, buildings and streets, i.e. clean them of radioactive material. A change of clothes and a thorough shower are usually sufficient to decontaminate a person. Contaminated clothes and shoes should be taken off before entering a building. The articles of clothing should be stored in a tightly closed plastic bag – this avoids the spread of radioactive material and allows for subsequent analysis. Decontaminating streets, squares and buildings is considerably more complicated; they must be sprayed with plenty of water and scrubbed, sometimes even vacuumed.

Depending on the type of contamination and the surface, this procedure eliminates 10% to 90% of the radioactivity – several repeat operations may be required to have any significant effect. Certain radioactive substances may combine with asphalt or concrete, thus rendering the above procedure ineffective.

In these cases it may be necessary to remove cladding from buildings, or street surfaces, and dispose of them as radioactive waste. For areas that cannot be decontaminated – such as gardens or parks – the topsoil has to be removed to a depth of 20-30 cm, requiring the disposal of great amounts of radioactive waste.

The army, the Protection and Support units and private companies would probably be deployed to cope with such a large-scale task. Moreover Switzerland has a radioactivity task force (Federal Emergency Organisation Radioactivity - EOR); its activities are defined and regulated by the above-mentioned VEOR decree.

All those participating in such a campaign would have to be monitored using a dosimeter, requiring the deployment of a number of other civilian, army and civil protection specialists. After successful decontamination the population could return home after a few days or months. A failed effort might require demolition and reconstruction of affected buildings, and/or the relocation of the population.

9. Possible economic or psychological impact of a radiological attack

In a densely populated area, thorough decontamination of even a relatively small zone would be likely to generate immense costs. Local companies would probably have to temporarily shut down; many inhabitants may take the opportunity to move out. Apart from these more or less direct costs, the uncertainty and shock suffered by large parts of the population would give rise to considerable general costs. Although the health risk might be marginal, the affected town or even region would lose much of its attraction for inhabitants, companies and even tourists.

This in fact brings us to the major hazard that a dirty bomb represents for contemporary society: until now its impact has been examined primarily from a technocratic point of view, according to the tacit assumption that the population would behave reasonably, without jeopardizing emergency management procedures. However, a United States survey shows that about 40% of the people would not follow official instructions, and would in any case attempt to flee the site as fast as possible.[7]

[7] Roz D. Lasker: Redefining Readiness: Terrorism Planning Through the Eyes of the Public, Center for the Advancement of Collaborative Strategies in Health, The New York Academy of Medicine, September 14, 2004.

The medium and long-term psychological repercussions of such an event can also only be estimated. The attacks on 11 September 2001 gave rise to numerous cases of post-traumatic stress syndrome, depression, insomnia, or anxiety. A study published in 2002 states that after the attack on the Twin Towers, over 67,000 Manhattan residents suffered from post-traumatic stress syndrome, and 87,000 became depressed.[8] Persons directly concerned, notably those who had taken part in the clean-up operations, may require years of medical assistance. Symptoms such as insomnia, anxiety attacks, attention deficit disorder and apathy are now widespread.

The psychological and political effects may affect much wider groups of the population. The example of 11 September offers a telling illustration of the effects of a devastating terrorist attack on national and international policy. In Afghanistan and Iraq a military alliance went to war against governments that had backed the terrorists. Control and safety measures inside the U.S. were considerably reinforced – in an open and democratic society this may present a potential danger to personal and civic rights. This has given rise to a fierce debate in the U.S. and internationally concerning effective ways to combat terrorism.

10. Summary and conclusions

A dirty bomb is a conventional bomb that contains radioactive material. When it explodes, this material is dispersed in the environment causing radioactive contamination. A well-organised terrorist group can probably construct and use such a bomb without too much difficulty. On the other hand, it may not be worth their while to do so – a dirty bomb does not have much greater direct impact than a terrorist attack with a conventional bomb of comparable strength, but is much more difficult and expensive to build. It causes the same number of immediate casualties. In comparison to immediate impact, the radioactive contamination it provokes is almost negligible, being too low to cause passers-by or inhabitants to suffer acute radiation sickness or death.

However, if no measures are taken to protect the population against the long-term effects of increased radiation, one might expect an increase in the incidence of cancer years or decades later. Appropriate measures can reduce these effects. In Switzerland the VEOR regulates the responsibilities, organisation and deployment of federal organisations in the event that the population and/or the environment are threatened by radioactivity. Depending on the type and degree of contamination, the measures might involve restrictions on being outside, a ban on harvesting, putting livestock out to pasture, hunting and fishing, possible evacuation of the most affected areas, and extensive decontamination or even demolition of buildings. However, it might not be necessary to conduct such highly complex and invasive measures (e.g. evacuation) immediately. The degree of hazard would leave enough time to prepare these measures carefully, without exposing the population to undue risk. However, whether the population would show the necessary trust and maturity is questionable; this might considerably increase damage.

Thus one might say that whereas the direct damage to life and limb as a result of a dirty bomb attack would be quite limited, economic damage – if the contamination were relatively severe – could hardly be avoided. Regardless of the fact that the evacuation and subsequent decontamination of a given area could pose serious technical and logistic difficulties, they would in any case be very costly. In a densely populated and built-up area these costs could amount to billions, without it being at all clear who would pay. To what degree would the Confederation, the affected canton, the affected municipality cover costs? What costs would have to be covered by private owners?

In view of the limited health hazards but possible serious economic repercussions of a dirty bomb, specialists seem by and large to agree that one cannot really call it a “weapon of mass destruction” and that “weapon of mass disruption“ is much more apt.

[8] RD. Marshall: If we had known what we know now: a review of local and national surveys following September 11, 2001. CNS Spectr. 2002 Sep; 7(9):645-9.

Terrorists may be tempted to use such a weapon to inflict material damage as severe and as long-lasting as possible. Hitherto this was apparently not their aim – they focused on inflicting maximum direct damage. Will this be the case in the future? Will they develop new strategies and types of attack? For the time being we can do no more than take informed guesses.

Whatever the case may be, in Switzerland too we must do everything to protect ourselves against a potential dirty bomb attack. Preventive measures to avert the illegal acquisition and misuse of radioactive substances must be improved worldwide. In Switzerland we have reached a satisfactory level in this area; existing loopholes are constantly being identified and filled, but coordinated international efforts are also required. The SPIEZ LABORATORY particularly backs the work of the IAEA. Swiss authorities are working on measures to reduce the feasibility of a dirty bomb attack and its potential repercussions. The SPIEZ LABORATORY is also involved in these efforts.

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