The Medical Consequences of Nuclear Weapons
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## PREFACE

This pamphlet was originally published in 1981 to bring to the attention of the general public, politicians and members of the medical and related professions, the catastrophic effects that the use of nuclear weapons would entail. It was written by Professor John Humphrey, FRS, Emeritus Professor of Medicine, University of London; Dr Martin Hartog, FRCP , Reader in Medicine, University of Bristol; and Dr Hugh Middleton, MRCP, Clinical Lecturer, Department of Medicine, University of Cambridge.

Due to recent public demand for information on the effects of nuclear weapons, MEDACT is updating the 1981 pamphlet and placing it on its website. The opportunity has been taken to make a number of (mostly technical) amendments to take account of changes since 1981.

Since 1981, a considerable increase in our knowledge of radiation's effects has occurred. The text of the pamphlet has not been amended to incorporate this new knowledge as it would require many changes. This is particularly the case with new information on the transport, distribution and deposition of radioactive fallout as a result of many Chernobyl studies. Readers wishing to learn more about these matters may wish to refer to The Other Report on Chernobyl which may be downloaded from www.chernobylreport.org

MEDACT hopes to produce a completely revised and up-to-date pamphlet on the health effects of nuclear weapons in 2007.

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February 2007

# The Medical Consequences of Nuclear Weapons

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# The Medical Consequences of Nuclear Weapons

## INTRODUCTION

The basis of all nuclear weapons is the splitting (fission) of atoms of either uranium-235 or plutonium-239. Fission is a process whereby the nucleus of an atom absorbs a neutron (released by the radioactive disintegration of uraniurn-235 or plutonium-239) and then splits, releasing energy and more neutrons or unstable radioactive fission products; this process is used in the 'atom bomb'. There is a practical limit to the explosive power of such weapons. However the temperatures they generate, amounting to tens of millions of degrees, are so great that they can also cause fusion reactions, in which the heavy isotopes of hydrogen, deuterium, and tritium, fuse to form helium with the release of even greater amounts of energy. This is the way in which the sun generates its enormous heat and the same reaction is used in the 'hydrogen bomb'. There is almost no limit to the explosive power of such weapons, which are sometimes referred to as 'fission - fusion' devices. Finally, the weapon can be enclosed in an outer casing of uranium-238, the atoms of which are split by high-energy neutrons released by the fusion reaction to yield further energy and considerable quantities of additional radioactivity.

Explosive power is generally expressed as quantities of high-explosive trinitrotoluene (TNT). One ton of TNT when exploded is estimated to release $10^9$ ( 1,000,000,000) calories of energy. Explosions of nuclear weapons are so powerful that they are expressed as thousands (kilo) and millions (mega) of tonnes of TNT. At the end of the Second World War, the most powerful single weapon of conventional high explosive was a l0-ton TNT bomb and the total amount of conventional high explosive used throughout the whole of the War has been roughly estimated as 5 megatonnes (1 megatonne = 1 million of tonnes = 1 Mt). In contrast, the single weapon dropped on Hiroshima was approximately 13 kilotonnes (1 kilotonne = 1 thousand tonnes = 1 kt) TNT in explosive power, and that dropped on Nagasaki approximately 22 kt. During the years 1945-1990 vast numbers of even more devastatingly powerful weapons were produced or tested, the largest an estimated 60 megatons in strength. From a peak of approximately 70,000 in 1986, there were considerable reductions in the numbers of nuclear weapons held by the USA, Russia and Britain. However, in 2006, the world arsenal of nuclear weapons still amounted to almost 27,000 warheads.

Currently a new generation of nuclear weapons is being researched and developed, including nuclear bunker busters and 'accurately targetable' low yield nuclear weapons. However evidence shows that even a 'small' weapon would have such disastrous blast, heat and radiation effects that it could in no way be considered discriminate under international law and would therefore be illegal. There are now nine countries with nuclear weapons: the USA, Russia, China, France, Britain, India, Pakistan, North Korea and Israel.

Nuclear weapons have been developed for more than 60 years, during which time there have been two nuclear weapon explosions in heavily populated areas and more than 2000 test explosions. A great deal is therefore known about their immediate effects and these can, to a considerable extent, be predicted.

The following text mainly describes the effects of a 1 Mt weapon whilst the tables refer to weapons of explosive power 1 kt, 75 kt, 1 Mt and 10 Mt. These examples have been used to illustrate the likely effects of tactical (1 kt), medium-range (75 kt) and strategic (1 and 10 Mt) nuclear weapons.

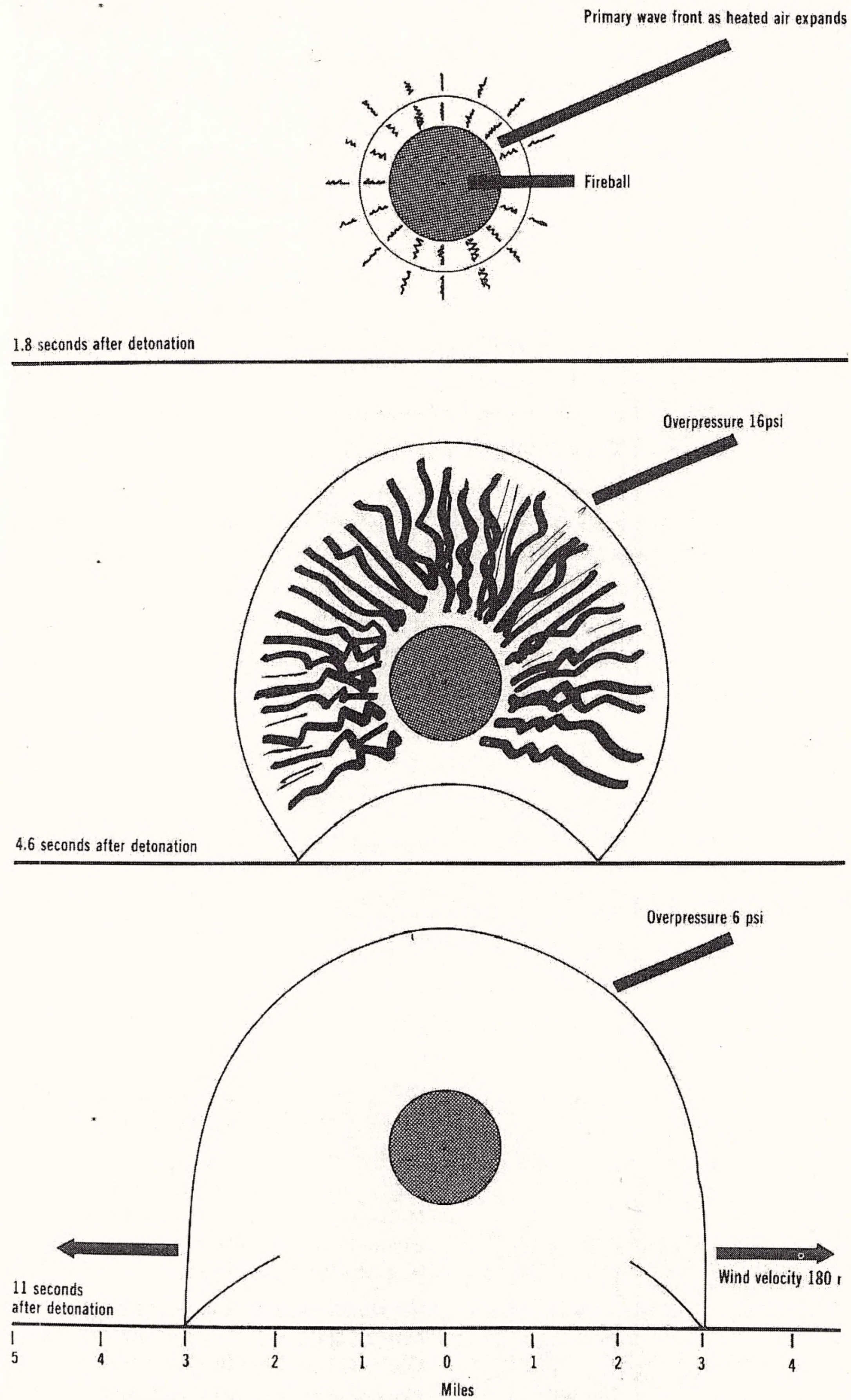
## THE EFFECTS OF NUCLEAR WEAPONS

An explosion is a sudden release of energy. When it occurs in air, a rapid expansion of gas in the region of the explosion causes a shock wave and other blast effects. Heat and, in the case of nuclear weapons, large amounts of radioactive matter, are also produced. Usually some 50% of the energy from the explosion of a nuclear weapon is released as the shock wave and other blast effects, 35% as heat and 15% as ionising radiation. Certain specialised devices such as the 'neutron bomb' have different partitions of effect. The effects of a nuclear weapon vary according to the height at which it is detonated. Blast and heat effects are experienced over greater distances if the explosion occurs well clear of the earth's surface (air burst), whilst greater local radioactive fallout, a crater and more effective destruction of structures on or underground are achieved with a surface detonation (ground burst). In addition, nuclear weapons can be detonated underwater, which produces a huge tidal wave and a cloud of radioactive water droplets, and underground, as in most test explosions. The point of the earth's surface closest to the centre of a nuclear explosion is called 'ground zero'.

### Blast

Rapidly expanding gases at the point of detonation give rise to a shock wave that travels from the centre of the explosion at supersonic speed (see Figure 1). The intensity of the shock wave is measured as the peak overpressure, which is the pressure of air within the wave in excess of normal atmospheric pressure.

Figure 1 The development of the blast wave after 1 Kt air burst


Primary wave front as heated air expands
Fireball
1.8 seconds after detonation
Overpressure 16psi
4.6 seconds after detonation
Overpressure 6 psi
Wind velocity 180
11 seconds after detonation
5 4 3 2 1 0 1 2 3 4
Miles

Nuclear weapons produce more prolonged shock waves than conventional weapons, which increase their destructive effect, and this is further enhanced by the very high winds that follow the wave. Blast intensity close to ground zero is enormous and amounts to 40 atmospheres within 660 meters of a 1 Mt surface explosion. As the shock wave travels away from ground zero it diminishes in intensity.

Table 1 Distance (km) from ground zero of peak overpressures after air bursts* of different-sized nuclear weapons

| | **Size of Nuclear Weapon** | | | |
|---|---|---|---|---|
| Peak overpressure (atmospheres) | **1 kt** | **75 kt** | **1 Mt** | **10 Mt** |
| 0.8 | 0.4 | 1.7 | 4.0 | 8.6 |
| 0.33 | 0.7 | 2.9 | 6.9 | 15 |
| 0.13 | 1.3 | 5.4 | 13 | 27 |
| 0.07 | 2.1 | 8.8 | 21 | 28 45 |

*detonated between 370m and 460m; reduce figures by 30% for ground bursts.

Table 1 gives the ranges of 0.8 to 0.07 atmospheres (atm) overpressures following air bursts of different sizes at between 400m and 500m. After a 1 Mt air burst an area with a radius of 4.0 km would experience a shock wave of at least 0.8 atm peak overpressure; outside this there would be a ring 2.9 km wide in which the peak overpressure would be between 0.8 and 0.33 atm. The ring beyond this of overpressures between 0.33 and 0.13 atm would be 5.9 km wide and for a further 8.0 km there would be a peak overpressure effect of between 0.13 and 0.07 atm.

Table 2 Effects on buildings of different peak overpressures

| **Peak overpressure atm** | **Peak wind velocity (km per hour)** | **Effects** |
|---|---|---|
| >0.8 | 510 | Most buildings destroyed, except some reinforced concrete structures |
| 0.33 - 0.8 | 260 | Lightly constructed commercial buildings and typical houses destroyed; cracks and instability in heavier structures |
| 0.13 - 0.33 | 150 | Walls of typical steel-frame buildings blown away; severe damage to dwelling houses |
| 0.07 - 0.13 | 55 | Damage to most structures; windows blown in; considerable risk of injury from flying glass. |

Table 2 summarises the likely effects on buildings of different overpressures. Within the 0.8 atm ring, there would be virtually total destruction of all buildings and there would still be considerable damage to houses as far out as overpressures of 0.07 atm. In addition to these effects of the blast wave, there would be further devastation from the winds that accompany it, with maximum speeds of 510 km per hour at 0.8 atm overpressure and of 260 km per hour at 0.33 atm.

The human body is relatively resistant to the direct effects of blast. Very high overpressures, however, cause potentially fatal effects such as rupture and haemorrhages of the lungs, air embolism and rupture of the gut and ear drums. Peak overpressures over 2 atm produced by nuclear weapons result in the death of approximately 50% of people exposed.

As people spend much of their time in and around buildings, most of the huge number of casualties from blast would be caused by the effects of collapsing buildings and flying projectiles, rather than direct effects of overpressure. In areas where buildings were almost completely demolished there would be little hope of survival; in areas where the damage was less there would still be a serious risk of injury from falling masonry or flying fragments of glass or other materials and, in the open, of being dashed to the ground by the high winds.

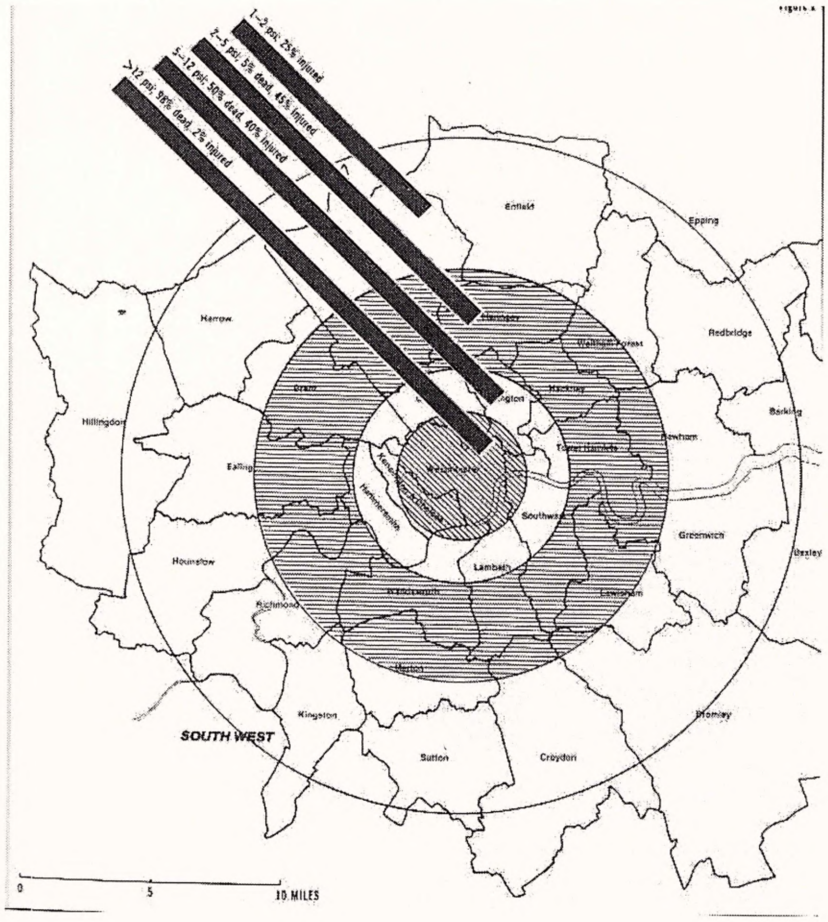
Table 3 Casualties in different peak overpressure zones

| **Peak overpressure - atm** | **Effects** |
|---|---|
| >0.8 | 98% dead; 2% injured |
| 0.33 - 0.8 | 50% dead; 40% injured; 10% safe |
| 0.13 - 0.33 | 5% dead; 45% injured; 50% safe |
| 0.07 - 0.13 | 25% injured; 75% safe |

Table 3 summarises the expected casualties within different peak overpressure zones based upon the degree of damage to buildings. The whole range of injuries seen with accidents in peacetime would be encountered such as fractures of limbs and the spine, damage to organs in the chest and abdomen and lacerations of all degrees of severity. Many would have multiple injuries.

Applying the figures from Tables 1 - 3 to a map of any area, one can obtain a picture of the blast damage and casualties that would be produced by different sized nuclear explosions (see Fig 2).

Figure 2: The extent of over-pressure effects after a 1Mt air burst 400m over central London




## Heat

The fireball of a nuclear explosion behaves like a small sun for an instant, radiating energy across most of the electromagnetic spectrum. It would appear to an observer 80 km away to be more brilliant than the sun at noon. Flash-blindness or dazzle would occur up to distances of 21 km on a clear day and 85 km on a clear night after a 1 Mt air burst. Retinal burns leading to permanent blindness could occur up to a distance of 51 km, but these burns are less likely as they depend upon the eyes being focussed on the source.

The intense heat generated by the explosion would inflict skin burns (flash burns) on people directly exposed to the fireball, the risk of which would depend upon the amount of heat required to produce burns and the distance to which such heat travels from the explosion. The amount of heat required to produce a burn is affected by the degree of skin pigmentation and the wavelength and duration of thermal energy emitted, both of the latter vary with the size of the explosion. The distance to which a fireball radiates heat is considerably affected by the weather conditions and is reduced with poor visibility.

Table 4 Distance in km at which burns of skin tissues would be sustained on a clear day after air bursts of different-sized nuclear weapons*

| Type of burn | Size of nuclear weapon | | | |
| --- | --- | --- | --- | --- |
| | **1 kt** | **75 kt** | **1 Mt** | **10Mt** |
| Partial thickness | 0.8 km | 5.2 km | 12.8 km | 27 km |
| Full thickness | 0.6 km | 4.4 km | 11.2 km | 22.4 km |

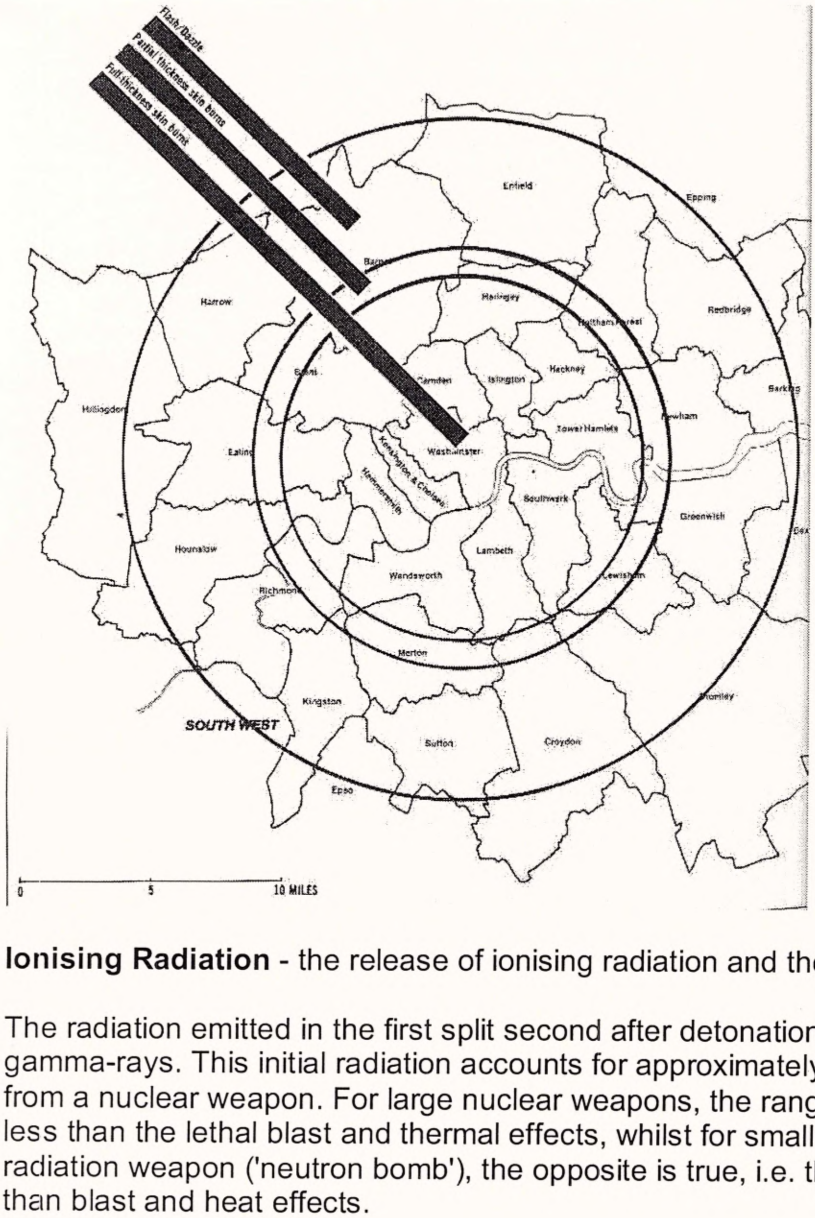
*reduce by 50% for ground bursts

Table 4 gives the distances from air bursts of different sizes up to which flash burns would be sustained, assuming clear weather conditions. A partial thickness burn is one in which the skin becomes blistered and may become infected and a full-thickness burn is one in which there is complete destruction of the skin. Both of these can result in death from rapid loss of body fluids from the surface of the burn, the amount of loss being proportional to the area of skin burnt. Replacement of body fluid is the immediate need of treatment together with avoidance of infection. Partial-thickness burns usually heal by themselves if they do not become infected, whilst full-thickness burns only heal very slowly with scarring and, under normal conditions, are usually treated by skin grafting. The number of people who sustain flash burns would clearly depend upon the number caught in the open at the time of the explosion.

In addition, fires would be started several miles from ground zero, resulting in many more burns (flame burns). These would arise partly from the heat wave setting light to inflammable materials and partly from blast damage to installations such as heaters, electrical equipment and gas pipes. Flame burns are likely to be associated with lung damage and toxic effects from the inhalation of smoke, especially from burning plastic, which account for the majority of immediate deaths in fires, particularly when the victim is trapped in a burning building. The main fire zones would extend up to 8 miles from ground zero after a 1 Mt air burst on a clear day and 5 miles on a day with poor visibility.

There would be a risk of firestorms, with violent inrushing winds and extremely high temperatures within the area affected, which would kill all of the people trapped within them - including those in shelters - by heat and asphyxiation. Firestorms developed in Hiroshima after the atomic bomb and in Hamburg and Dresden after massive 'conventional' bombing. Although the risk of firestorms in British cities is considered to be small from considerations of the density of housing and the type of building materials, the possibility exists since there are large amounts of readily flammable material such as motor fuel and rubber tyres and widely-distributed gas and electricity networks in present-day cities. Figure 3 illustrates the ranges to which full-thickness and partial-thickness flash burns of the skin and flash dazzle would be sustained after a 1 Mt air burst over central London.

Figure 3: Areas receiving sufficient heat after a 1 Mt air burst 500m over central London to cause skin burns and flash dazzle




**Ionising Radiation** - the release of ionising radiation and the spread of radioactive materials

The radiation emitted in the first split second after detonation consists mostly of neutrons and gamma-rays. This initial radiation accounts for approximately one third of the total radiation dose from a nuclear weapon. For large nuclear weapons, the range of lethal initial ionising radiation is less than the lethal blast and thermal effects, whilst for smaller weapons, especially the enhanced radiation weapon ('neutron bomb'), the opposite is true, i.e. the initial radiation effects are greater than blast and heat effects.

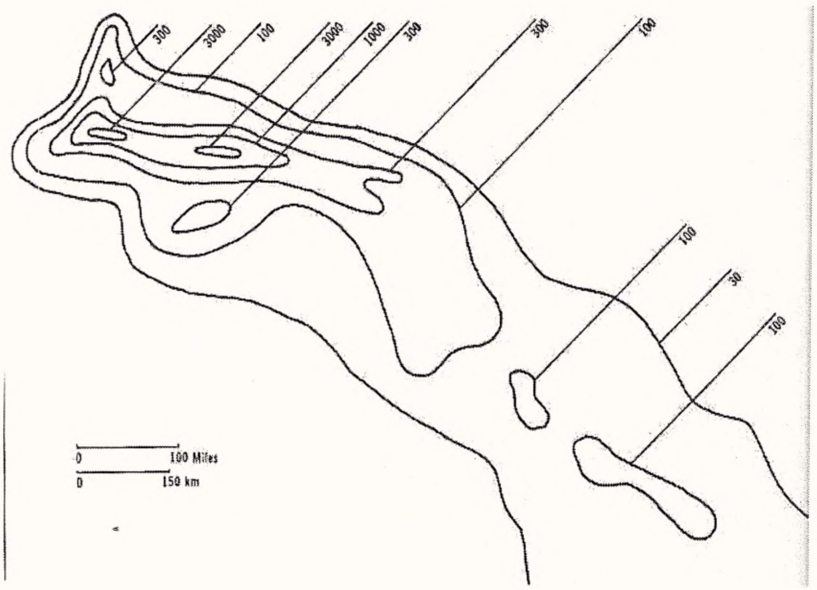
A nuclear bomb also produces large quantities of radioactive isotopes (radionuclides) by fission and by neutron activation. Over 300 radioisotopes are thereby formed which emit alpha-, beta- and gamma-radiations and these are carried upwards by the accompanying fireball.

If the nuclear explosion is a ground burst, the radiation effects are worse. This is because the fireball and resulting winds will suck huge amounts of dust and other debris from the ground. These are also swept upwards by the fireball. The radioactive isotopes produced by the bomb condense on this debris to produce radioactive clouds which may be transported for varying distances then deposited back to earth as radioactive **fallout**. Some of the radioactive products fall to the ground on larger particles over the first 24 hours producing massive local contamination. The remaining delayed fallout condenses on fine particles, rises high into the atmosphere and falls to the ground at varying distances from the bomb centre over much longer time periods.

The pattern of fallout deposition is highly variable. It is affected by many factors, including the size and type of weapon, height of explosion, wind pattern, and especially **rainfall**. The radioactivity in fallout declines with time depending on the half-lives of the radionuclides concerned. Many released radionuclides decay very quickly within a few hours. Others have half-lives measured in days, for example iodine-131 (half-life 8.3 days) which means that most activity has disappeared after 2 to 3 months. However other nuclides such as caesium-137 and strontium-90 have ~30 year half-lives. This means that residual amounts of such nuclides persist to this day throughout the world from the atmospheric bomb tests of the 1950s and 1960s. Alpha emitters can have half-lives of many thousands of years; for example plutonium-239 has a half-life of 24,400 years.

If the amount of radioactivity at a specified time after a single explosion is known, it is possible to calculate the radioactivity at any subsequent time and to estimate the total radiation dose received over a given period. Since the radioactive plume and its fallout move with the prevailing winds, early or local fallout is spread over an elongated area extending downwind from the explosion point. Elliptical, or cigar-shaped, areas whose contours represent different dose rates illustrate this. Where strong or variable winds exist with varying wind speeds at different altitudes, turbulence and washout by rain can lead to irregular dose rate contours, as illustrated by the results of one of the surface test series shown in Figure 4.

Figure 4
Dose contours (cGy per hour) after a test of a 10Mt 50% fission surface burst in a 50 km per hour wind




Nevertheless, calculations of idealised fallout distributions give some idea of the area enclosed within any specified dose-rate contour. Such calculations have been made from theoretical considerations and from measurements of actual fallout deposition. Tables 5A and 5B give the dimensions of 10 and 3 grays per hour dose-rate contours from ground bursts of various yields. It is important to remember that, as fallout radioactivity consists principally of fission products, it is proportional to the **fission** yield and not the **total** yield of the weapon. Relatively small weapons can be assumed to be entirely fission weapons but large weapons are fission - fusion reactions and have been assumed here to have a 50% fission yield.

Table 5A
Approximate dimensions and areas of a **10 Gy/hr dose-rate contour**, 1 hour after ground bursts of different sized nuclear weapons, assuming no cloud effects and steady wind of 24 kph

| | Size of nuclear weapon | | | |
|---|---|---|---|---|
| | **1 kt** | **75 kt** | **1 Mt*** | **10 Mt*** |
| Downwind distance - km | 2.9 | 20 | 43 | 120 |
| Maximum width - km | 0.06 | 0.16 | 6.4 | 43 |
| Ground zero width - km | 0.1 | 1.1 | 5 | 18 |
| Area - $km^2$ | 0.13 | 24 | 220 | 4,100 |

* assuming 50% fission yield

Table 5B
Approximate dimensions and areas of a **3 Gy/hr dose-rate contour**, 1 hour after ground bursts of different sized nuclear weapons, assuming no cloud effects and steady wind of 24 kph

| | Size of nuclear weapon | | | |
|---|---|---|---|---|
| | **1 kt** | **75 kt** | **1 Mt*** | **10 Mt*** |
| Downwind distance - km | 7.2 | 50 | 96 | 270 |
| Maximum width - km | 0.2 | 4 | 12 | 70 |
| Ground zero width - km | 0.3 | 3 | 7 | 20 |
| Area - $km^2$ | 1.3 | 140 | 1000 | 16,000 |

* assuming 50% fission yield

A population exposed to an initial dose-rate of 3 Gy/hr from fallout would still be exposed to a dose rate of about 0.1 Gy per day 10 days later. A population exposed initially to a dose-rate of 10 Gy/hr would still be exposed to 0.5 grays per day after 7 days and 0.1 grays per day after 25 days.

Assuming the population is evacuated, what matters is the total accumulated dose of radiation rather than the dose rate. In areas close to ground zero this can be calculated from the known rate of decay of the main remaining nuclides: at further distances account has to be taken of the decay between the explosion and arrival of the fallout cloud.

Table 6 Approximate dimensions in km and sq km of areas receiving different accumulated radiation doses during first 2 weeks after a test 1 Mt 50% fission yield ground blast

| Downwind Distance km | Maximum Width km | Area $km^2$ | Ground Zero Width km | Accumulated dose (grays) after 2 weeks |
|---|---|---|---|---|
| 290 | 34 | 9900 | 16 | 0.9 |
| 220 | 28 | 6200 | 14 | 1.5 |
| 130 | 17 | 2200 | 12 | 4.5 |
| 80 | 12 | 940 | 10 | 10 |

Figure 5 Approximate dimensions of radiation dose contour accumulated over 2 weeks after a 1 Mt 50% fission yield ground burst on Bristol in a 24 kph wind

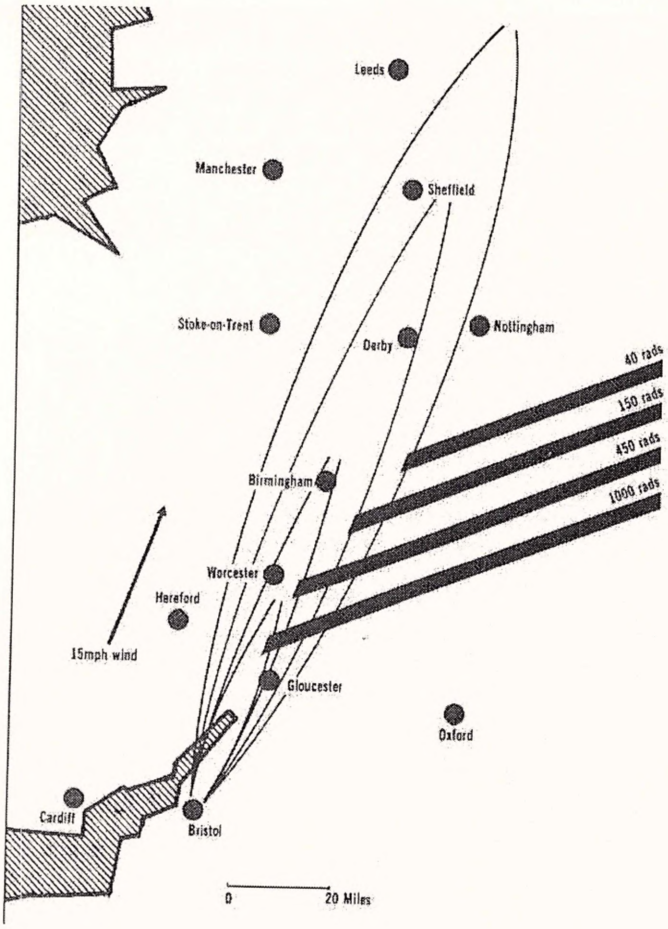
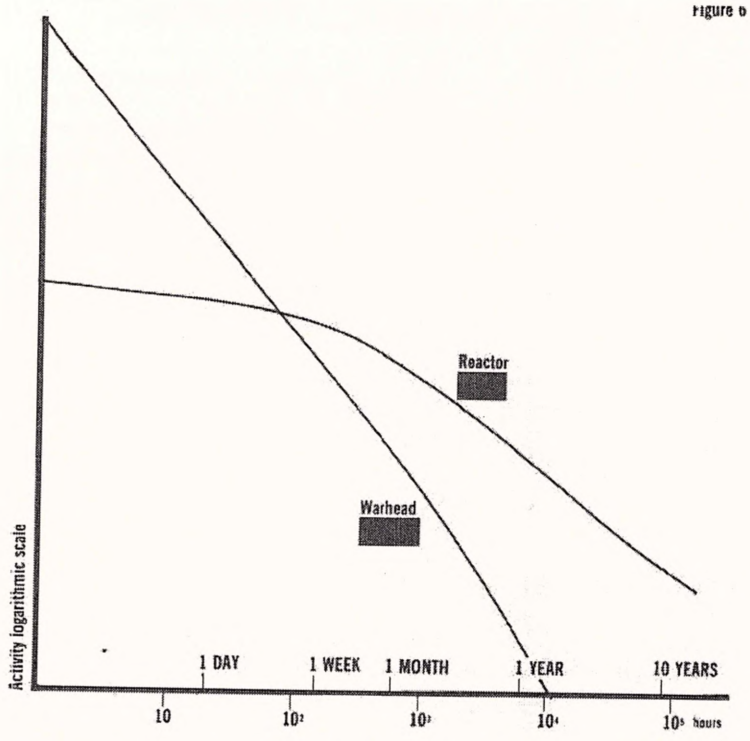



Table 6 and Figure 5 above show the dimensions of the areas that would receive different cumulative doses of ionising radiation in the first 2 weeks after a 1 Mt 50% fission yield explosion, assuming a steady 24 km per hour wind. The International Commission on Radiological Protection presently recommends 0.1 centigrays (1 mGy) per year as the limit of exposure to ionising radiation for members of the public (assuming exposure to low-LET radiation).

After a nuclear attack, however, the public would almost certainly have to inhabit contaminated areas receiving higher dose rates. A 1 Mt weapon would create a zone of 3,000 km$^2$ with a dose rate of 20 mGy per year for at least a year. Larger areas would remain contaminated for shorter times. With multiple overlapping explosions, contamination would be far more severe and widespread.

If a nuclear power station or nuclear waste disposal site were the target of a nuclear attack, the radioactive isotopes released would contain a larger proportion of those with slow rates of decay than after the explosion of a nuclear weapon. This possibility is by no means remote bearing in mind the strategic importance of sources of energy and the role of nuclear reactors in the manufacture of warheads. Furthermore, nuclear reactors may be close to military installations in densely populated regions, such as central Europe. After a time the overall level of activity would be determined not by the more rapidly decaying isotopes from the weapon but by the more slowly decaying isotopes such as Cs-137 and Sr-90 with 30 year half-lives (see Figure 6). It has been estimated that such an event would result in the contamination of an area of some 64,000 km$^2$, nearly three times the area of Wales, with a dose rate of at least 20 mGy per year for a year; an area of 460 $km^2$ would be contaminated for more than a century.

Figure 6
Activity decays of radionuclides released by (A) 1 Mt warhead and (B) destruction of a 1 gigawatt nuclear reactor by a nuclear weapon



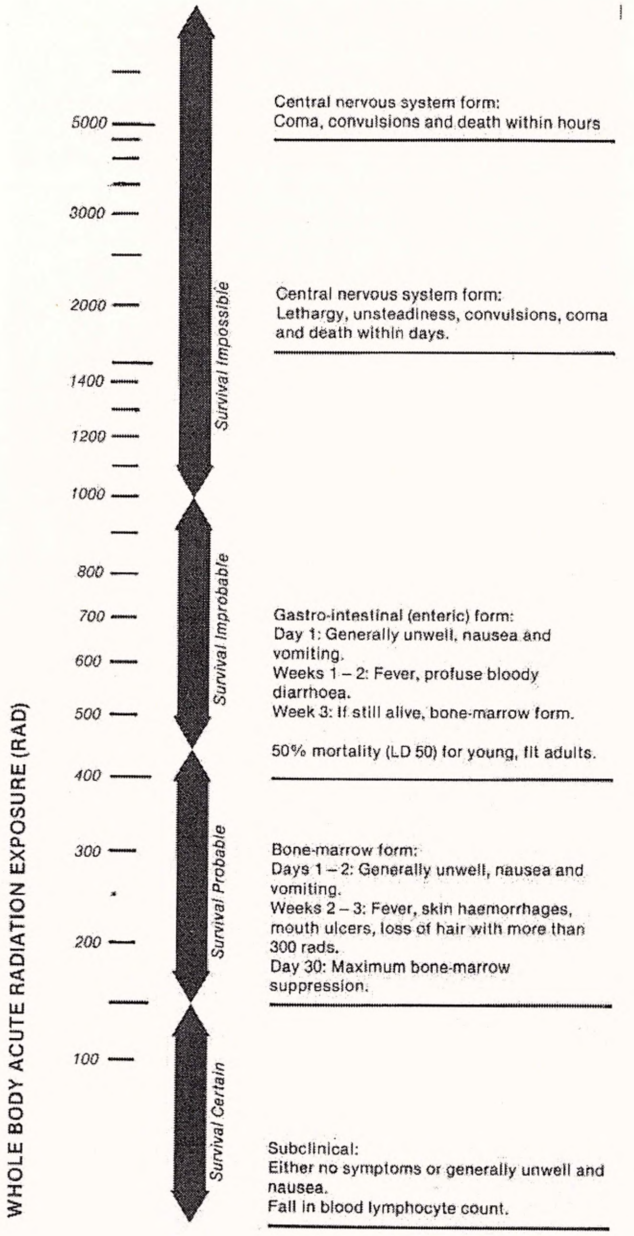

X axis = time after explosion/destruction (linear scale)
Y axis = activity remaining (logarithmic scale)

## MEDICAL EFFECTS OF IONISING RADIATION

Ionising radiation causes damage particularly to rapidly dividing cells such as those of the bone marrow and the lining of the gastro-intestinal tract. When the whole body is exposed to large doses of radiation in a relatively short period of time (e.g. 1 gray* (Gy) within an hour or so), a number of deterministic (i.e. with a threshold) effects occur including dizziness, nausea and vomiting, diarrhoea, prodromal effects, and eventually death. Most deaths are usually due to opportunistic infections to which the body is vulnerable because of the destruction of its immune system by radiation. A dose of approximately 6 Gy[1] results in the death of about 50% of young, fit adults exposed and hence is known as the LD 50 (LD stands for lethal dose). In elderly people, children and those who are ill, the LD 50 is lower. Three main varieties of radiation effects, which can exist together, are summarised in Figure 7.

[1] A gray is a unit of absorbed radiation dose is used here and elsewhere in the text though, strictly speaking, the unit of biological dose should be the sievert (see Appendix I).

Figure 7 Early Radiation Effects (1 rad = 1 cGy = 0.01 Gy)




**Bone-marrow effects** occur after exposure of the whole body to more than 1.50 Gy. There is a short-lived early period of symptoms such as lethargy and nausea, followed by a symptom-free period of about 10 days. Towards the end of the second week, there is maximum depression of certain blood constituents. These include white blood cells which counter infections and platelets which prevent bleeding. Loss of white blood cells results in susceptibility to infections and the development of spontaneous haemorrhages. These effects may be fatal, usually at the end of the fourth week after exposure or the subject may gradually recover.

**Gastro-intestinal ('enteric') effects** occur with higher doses of radiation (>1.5 Gy). The main initial damage is to the cells lining the small intestine. This results in massive diarrhoea with loss of body fluids and the risk of septicaemia from bacteria that have gained access through the damaged lining. These symptoms occur earlier than in the bone-marrow form and, if the subject survives, are likely to be followed by the features of the bone-marrow form described above.

Finally, at still larger doses, **central nervous system effects** occur which at massive doses (>100 Gy) results in convulsions, coma and death within a few hours. At somewhat lower doses, there is a gradual loss of mental and physical activity, followed by disorientation, coma and death in a few days.

Another effect of ionising radiation that would be encountered in the first few days after explosion with high levels of fallout, would be burns of the skin produced by particles emitting beta-radiation falling on the skin. The developing foetus is particularly sensitive to ionising radiation. Damage to brain growth was found in Japan in children whose mothers were less than 15 weeks pregnant at the time of the atomic bombings and who were exposed to more than 2 Gy. Smalls skulls (microcephaly) occurred in 44% of surviving children and 16% of these were severely mentally-retarded. Furthermore, there was an increased incidence of still births and of deaths in the first year of life in the children of mothers exposed late in pregnancy.

The long-term effects of radiation (especially cancer) occur several decades after the explosion due to the long latency periods of cancer. These cancers arise a late consequence of exposures to initial nuclear radiation and to fallout. It should be noted that continued exposures to long-lived radioactive isotopes is likely to occur (see Appendix 2). These isotopes may enter the body by ingestion, inhalation and (more rarely) through the skin.

From studies of the survivors of the atomic bombs in Japan, and of patients receiving X-rays for diagnostic or treatment purposes, exposure to ionising radiation has been found to increase the risk of the later development of leukaemia and other forms of malignant disease. The incidence of all types of leukaemia (except chronic lymphocytic) is increased with the peak incidence in Japan occurring 6 years after exposure. The incidence of solid cancers of many tissues - in particular thyroid, bone, breast and lung - is also increased by radiation. Radiation-induced solid cancers occur later than leukaemia with a latent period of 20- 25 years. Differences of expert opinion exist as to the exact extent of the risk of developing radiation-induced malignancies; Table 7 shows the risks of radiation-induced cancer death estimated by the International Commission on Radiological Protection (ICRP). The current overall risk is roughly 5 in 100 for each Gy of accumulated exposure, which means that persons exposed to a wartime emergency dose of 1.5 Gy (in 24 hours) would be exposed to the risk of approximately 7.5 in 100 of later dying from a radiation-induced cancer.

The risk of genetic abnormalities arises from the effects of radiation on the ovum and the sperm-producing cells. Although an increased incidence of genetic defects has, so far, not become apparent after the atomic bombings in Japan, gene mutations are usually recessive, which means that their effect would not become manifest for many generations. Certainly, an increased number of chromosomal abnormalities in cultures of white blood cells have been demonstrated in survivors of the Japanese atomic bombs examined 20 years later. The doubling dose for spontaneous mutations in man has been estimated as being between 0.5 and 2.50 Gy, a dose likely after a nuclear attack.

Another consequence of exposure to radiation is an increased incidence of infertility, some of which in women may be due to the spontaneous abortions of foetuses with severe genetic abnormalities. In Japanese survivors of the atomic bombs, there has been an increased incidence of eye cataracts that has been attributed to the effects of irradiation.

Table 7 Estimated risk of dying from radiation-induced leukaemias and cancers. Risks are expressed as the number of cancer deaths per million persons exposed to 10 mGy.

| CANCER | Risk |
|---|---|
| Leukaemia | 20 |
| Bone cancer | 5 |
| Lung cancer | 20 |
| Thyroid cancer | 5 |
| Breast cancer | 25 |
| All other cancers | 50 |

## HIROSHIMA AND NAGASAKI

In July 1945 the first test atomic bomb was exploded. Three weeks later at 8.15 a.m. on August 6th a uranium-235 bomb of 13 kt approximate yield was exploded 550m above Hiroshima. 3 days later a plutonium-239 bomb was dropped on Nagasaki of 22 kt approximate yield.

Hiroshima had a civilian population within the affected area of roughly 256,000. Casualty figures from the atomic bombings are approximate but about 68, 000 were killed and 76, 000 injured in Hiroshima: additional thousands were subsequently missing and never accounted for. Nagasaki had a population of roughly 173 800 of whom about 38 000 were killed and 21 000 injured. The descriptions below deal mainly with Hiroshima.

### Physical effects

Within seconds of detonation a rapidly expanding fireball developed into a mushroom cloud. Houses 1.6 km from ground zero caught fire from the direct effects of thermal radiation. Mica (melting point 900°C) fused on granite gravestones, while clay tiles (melting point 1300°C) melted half a kilometre from the explosion. The blast devastated even the largest buildings. Dr Fujii's Private Hospital, 1.5 km from ground zero toppled into the Kvo River. A firestorm developed which lasted for 6 hours and burned an area of 19 $km^2$. The fires were fanned by winds of 50 - 60 km per hour rushing towards the centre of the devastated city. 60,000 houses out of a total of 90,000 were destroyed. Many buildings became piles of rubble. The Museum of Science and Industry was left with its dome stripped to its steel frame, 'as if for an autopsy'.

### Description of the scene

No one could understand what had happened. Thousands began to flee the city. Most of them seemed to be hurt or maimed. Eyebrows were burned off, skin was hanging from faces and hands. Some were vomiting. 'Almost all had their heads bowed, looked straight ahead, were silent and showed no expression whatsoever'. 'In general, survivors that day assisted only their relatives or immediate neighbours, for they could not comprehend or tolerate a wider circle of misery.'

Towards evening the streets became quieter: 'Now not many people walked in the streets but a great number sat and lay on the pavement, vomiting, waited for death and died.' Even now there was no organised help. Masses were dead, masses were still dying. 'They all felt terribly thirsty and they drank from the river. At once they were nauseated and began vomiting and they retched the whole day'. There were a few people who were capable of helping others. When Mr Tanimoto arrived at Asano Park 'it was very crowded, and to distinguish the living from the dead was not easy, for most of the people lay still with their eyes open'. Continuing fires whipped up by the wind forced vast crowds towards the rivers. Those near the banks were pushed in and drowned.

Survivors that evening noted that the asphalt on the streets was still too hot to walk on with comfort. Two men noticed 'a pumpkin was roasted on the vine', which was eaten. Potatoes under the ground were found to be baked and were gathered for food. Many desperately ill survivors found their way to the sand pits on the river deltas. The tide was coming in.
Many were too weak to move themselves but were helped by exhausted survivors. 'He reached down and took a woman by the hands, but her skin slipped off in huge glove-like pieces.' Others were moved up the sand pit but the following morning they had gone, as the tide had come higher than expected.

During the first day, Father Kleinsorge was asked to help some soldiers. 'When he had penetrated the bushes, he saw there were about 20 men and they were all in exactly the same nightmarish state; their faces were wholly burned, their eye sockets were hollow, the fluid from their melted eyes had run down their cheeks.' This was the result of having their faces upturned when the bomb exploded.

**Medical effects**

The doctors involved with care of the casualties had to work in appalling conditions with an unbelievable workload dealing with a 'disease' new to mankind. Many of the hospitals were partially or totally destroyed and only three out of the original 45 in Hiroshima were unscathed. 65 of the 150 doctors were killed outright and most of the rest were wounded. 1,654 of the original 1,780 nurses were dead or too badly wounded to work. The Red Cross Hospital, the largest in the city and approximately 1.6 km from the explosion was badly damaged. Only six of its 30 doctors and ten of its 200 nurses were able to continue with their duties.

At first, the hospital doctors could not understand how even those not caught in house fires could receive such terrible burns. Because of the high numbers of casualties and lack of facilities, many of the thousands of Hiroshima's burned victims were inadequately treated or received no treatment at all. From the day after the bombing, burns accounted for approximately 50% of deaths; 53% of those ~l km from the explosion who sustained burns died within the first week and 75% died within 2 weeks.

There was a peak mortality on day 4 and a second peak at 3 - 4 weeks, though radiation effects complicated these latter fatalities. The vast majority of burn and blast casualties never reached hospital. Those who did get there did not have much chance of survival if more than slightly injured. Doctors working in the Red Cross Hospital could not understand why more and more casualties were coming in. 'Before long, patients lay around on the floors of the wards, and the laboratories and all the other rooms, and in the corridors and on the stairs, and in the front hall... '. 'Dr Sasaki had not looked outside all day; the scene inside was so terrible and so compelling that it had not occurred to him to ask any questions about what had happened beyond the windows and doors. 'Ceilings and partitions had fallen; plaster, dust, blood and vomit were everywhere. Patients were dying by the hundreds but there was nobody to carry away the corpses... thousands of patients and hundreds of dead were in the yard and on the driveway.'

Fairly early on doctors and survivors began to realise that something strange and terrible was going on. Many people without apparently severe burns or injuries began to collapse and die. This was the now well-documented condition of radiation sickness which produced many more casualties in Hiroshima than in Nagasaki because of the differences between the two bombs. Both bombs were exploded high above the cities and so caused ionising radiation, and perhaps more fallout that previously admitted.

Approximately 40,000 persons entered Hiroshima soon after the explosion to help with rescue work. Those entering within the first 3 days were exposed to lingering radiation and, together with the exposed survivors, subsequently showed an increased incidence of leukaemia and sold cancers.

**Other effects**

The immediate physical effects upon the cities were fire and destruction of buildings. The central area of Hiroshima became an inferno into which no fire-fighting force could enter. Streets and access were full of debris. In Hiroshima, 70% of the city's fire-fighting equipment was destroyed and 80% of firemen did not report to their posts. There was a drastic shortage of basic supplies including medical equipment, beds or mats for patients, food, safe drinking water and reasonable shelters for those who survived. Normal public health measures were not immediately available. Thousands of dead bodies had to be disposed of and initially there were inadequate resources for this. Power supplies and the electric grid system were shattered.

As described, the normal pattern of hospital care was entirely disrupted.
However, surrounding areas and communities had not been affected and were able to help both cities fairly quickly. Many survivors resigned themselves to the devastation caused by the bombs. However, when the long-term effects of radiation became known they developed a great hatred for those responsible for having used such weapons.

The authors gratefully acknowledge 'Hiroshima' by John Hersey as a source of material for this description of events in Japan.

## MEDICAL CONSEQUENCES OF A NUCLEAR ATTACK

THE DESCRIPTION of the effects of the use of nuclear weapons in Japan gives some idea of the possible consequences of a nuclear war, but there are several important differences between those experiences and the present situation.

Today there are nine nuclear-weapon states, four more than when the Non-Proliferation Treaty entered into force in 1970; estimates of their stockpiles are given in the box below. All but a thousand of today's 27,000 nuclear warheads are held by the USA and the Russian Federation. Yield of US weapons range from 100 to 450 kilotons equivalent of high explosive, of Russian from 100 to 750kt. In comparison the yield of the Hiroshima bomb was 15kt and of the Nagasaki bomb 20kt. While today's weapons, if ever used, would mainly be precisely aimed at military targets, but many of these are close to population centres. Centres of government would also be directly attacked. The use of ground bursts, the far greater yield of today's weapons, and the likelihood that many would be used in any exchange, implies massive casualties, including many among civilians, non-combatants and neutrals, from the direct effects and from local and global radioactive fallout. Hiroshima and Nagasaki are some distance apart and there was relatively little disruption of surrounding areas at the time. There was scope, therefore, for help from outside; today there would be little possibility of such help. Although Hiroshima and Nagasaki were centres of population they were small by present-day standards and less densely populated. For these reasons the effects of nuclear weapons today would be far more devastating than those experienced in Japan.'

Table 8: estimates of stockpiled nuclear weapons

**Nuclear Arsenals**

| Country | Weapons |
|---|---|
| United States | 10,000 |
| Russia | 16,000 |
| France | 350 |
| Britain | 200 |
| China | 200 |
| Israel | 75-200 |
| India | 40-50 |
| Pakistan | 24-48 |
| North Korea | ? |

NB: US and Russian totals include both deployed strategic and tactical warheads and those in reserve.

**Casualties**

Early casualties would be mainly from the effects of blast and heat with weapons of 20 kt or more; with weapons of less explosive power a proportion of casualties would suffer radiation sickness due to immediate nuclear radiation. With ground bursts there would be many additional victims of radiation sickness from fallout. From the experiences of Hiroshima and Nagasaki and the results of test explosions, calculations of estimated deaths and injuries from the effects of a single nuclear weapon can be made using the ranges of effects described earlier and knowledge of population statistics. Several detailed predictions of the numbers of such casualties have been carried out.

**An attack upon London**

In the 1980 'Square Leg' NATO exercise, 'an attack' upon London was modelled using five nuclear weapons (see Table 8). Based upon the 1971 census, when the population of Greater London was 7.2 million (private householders only), blast effects alone would have resulted in 1.1 million immediate deaths and 2.4 - 2.9 million injured. If only 1% of the population were directly exposed to the effects of heat in the open there would have been approximately 28,000 partial-thickness and 5,000 full-thickness burns among those who had not been killed or injured by the effects of blast. If 25% had been exposed, the corresponding figures would have been 700,000 partial-thickness and 125,000 full-thickness burns.

Table 9 Description of 'Square Leg' exercise attack on London in 1980

| Target | Size of weapon (Mt) | Height of explosion |
|---|---|---|
| Heathrow | 1 | ground burst |
| Heathrow | 2 | 366m |
| Croydon | 3 | ground burst |
| Brentford | 2 | ground burst |
| Potters Bar | 3 | 427m |

## Nuclear Attack

These figures may in fact be conservative as only simple additive effects are assumed for the overlap of multiple weapons, and also the distribution of the five weapons did not seem deliberately designed to inflict the maximum number of casualties. It is possible to imagine a different distribution of the same weapons that would have resulted in even more casualties. Most of those who survived the blast and heat effects would have been exposed to potentially lethal levels of fallout.

## A Modelled Attack upon Detroit in the United States

Detroit occupies an area of 262 $km^2$ with a population of 1,320,000. A 1 Mt ground burst would cause 220,000 deaths and 430,000 injuries from blast alone. Of the blast survivors (whether injured or not) if 1% were directly exposed to the effects of heat there would be a further 1,000-8,000 deaths and 500-3,000 injuries from burns, depending upon the visibility. If 25% of the population were exposed the corresponding figures would be 30,000 – 190,000 and 1,100-75,000. With an air burst the number of deaths and injuries from blast alone would be 470000 and 630,000 respectively.

Predictions of overall casualties from a full-scale nuclear attack are extremely difficult and vary as widely as between one quarter and three quarters of the population killed depending upon whether the best or worst conditions are assumed. However, the numbers of dead and injured would undoubtedly be on a scale never before encountered. There are a number of reasons why such predictions are so difficult. There are many different factors such as the weather conditions, density of housing and local terrain that would affect the physical effects of the weapon. Movements of the population at different times of the day and seasons of the year would greatly affect the number of people at risk. The extent and effectiveness of sheltering would be very much affected by the amount of warning of an attack. It is very difficult to make calculations for the overlapping effects of multiple explosions.

Finally, predictions such as those for London and Detroit given above are necessarily underestimates, as they are based only upon the immediate blast and heat effects and do not include casualties from other effects such as fires and fallout. Furthermore, after an attack there would be a number of even less predictable events such as epidemics, famine, and exposure to the cold, that might greatly further increase the number of casualties. Indeed the US Office of Technology Assessment Report (The Effects of Nuclear War) opens with the statement: 'The effects of a nuclear war that cannot be calculated are at least as important as those for which calculations are attempted.'

## Care of the Injured

As in Hiroshima and Nagasaki, the effect of a nuclear attack would overwhelm medical resources. Casualties would include a large number of patients with serious blast injuries, such as multiple fractures, crush injuries and severe lacerations. These require treatment with blood transfusions, surgery and drugs such as antibiotics and pain killers. For the effective resuscitation of the victim of a moderately severe injury, such as a closed fracture of the femur (thigh), transfusion with 2- 3 units (pints) of blood is often needed, and more if the injuries are more severe. There would also be a vast number of lesser injuries including many lacerations. Normally each of these would be carefully cleaned and some would need to be stitched. Patients with both severe and minor wounds are at risk from tetanus and require preventive treatment with either tetanus toxoid, antiserum or both.

Burns need particularly careful attention. Life-threatening losses of body fluid can occur and prompt infusions of plasma and other intravenous fluids are required. An average adult with burns affecting 50% of the body surface will need 10 or more litres of plasma in the first 48 hours. Infections are a particular hazard and in peacetime, patients with severe burns are nursed in isolation to try to prevent this, whilst minor burns are covered with sterile dressings. Antibiotics may be needed, and, under normal conditions, laboratory tests are used to decide which antibiotics are appropriate. More serious skin burns require specialist attention. In the whole of the UK there are specialised facilities for treating 400-500 patients with severe burns.

Modern medical care requires facilities that would be at risk of destruction in a nuclear attack, particularly as many of them are in city centres. It has been estimated that, after the hypothetical 'Square Leg' attack on London, only approximately 24 000 of the present 60 000 hospital beds would remain, of which about 15 000 would be equipped, initially at least, to handle casualties.

Clearly not many of the approximately 2.5 million injured and 250000 burned could receive hospital treatment. Assuming doctors to be evenly distributed within the population at the time of the attack, about 4,000 – 6,000 of the original 11,500 would be expected to survive. If all the casualties could be brought to them and they were prepared to work regardless of radiation risks, for 18 hours a day seeing each patient for 20 minutes, it would take between 7 and 17 days for all the injured to be examined and receive whatever treatment was available. However, even this estimate is over-optimistic as it ignores the effects of fallout risks that would in practice seriously hinder the mobility both of doctors and of patients. In the case of a single 1 Mt ground burst on Detroit it has been estimated that only 5,000 hospital beds would be available for the approximately 430,000 injuries and 25,000 burn casualties; such an attack would seriously overburden many regional medical facilities in the United States.

In practice, therefore, only first-aid care would be provided for the large majority of the injured. Even so, resources would be insufficient and efforts frustrated. Falling debris and ruined vehicles would make virtually all streets impassable and most injured people would have to be left untended. Those able to reach any sort of first-aid facility would rapidly swamp such resources, whilst those not able to find their own way would be left to fend for themselves.
There are no sufficiently large stocks of vital medicines such as antibiotics and it would be very expensive to maintain such stocks, as many drugs have limited shelf lives. The North West London Regional Blood Transfusion Centre has a stock of only 1,000 units (pints) of blood and it is unlikely that there would be enough volunteers to donate blood in the early days after a nuclear attack. Before long, stocks of blood plasma, antibiotics and analgesics would run out; the more severely injured would have to be left to die for want of transfusions, wounds would become infected and there would be no relief from pain.

Preventable or treatable conditions that would occur and would be fatal include blocked airway, blood loss, fluid loss from burns, gas gangrene, septicaemia and tetanus. The quality of medical care available would be little better than that found on a medieval battleground and even then only available to a small proportion of the needy. Patients needing long-term drug treatment, such as insulin-dependent diabetics, would die from a lack of supplies. In recognition of the likely absence of medical supplies, at least one set of Regional Health Authority planned for the provision of medical services in time of war includes an extensive list of herbal remedies which may have to be used for the treatment of medical conditions.

**Psychological Effects**

Survivors who escaped physical injuries would not escape profound psychological effects. To quote from an eye witness account of Hiroshima: 'shortly after the blast, those who were able, made a mass exodus from the city. There was no organised activity. The people appeared stunned by the catastrophe and rushed about as jungle animals suddenly released from a cage. Some few apparently attempted to help others from the wreckage, particularly family and friends. Others assisted those who were unable to walk alone. However, many of the injured were left trapped beneath collapsed buildings as people fled by them in the streets. The primary reaction to the bomb was fear-uncontrolled terror strengthened by sheer horror of the destruction and suffering witnessed and experienced by the survivors'.

There have been a number of studies of the psychological reaction to the Japanese atomic bombings and other major disasters such as earthquakes, though it would be impossible to speculate on the overall response to a disaster of such magnitude as a full-scale war with nuclear weapons. One reaction could be extreme panic accompanied by frantic searching for family members who were away from home at the time of the disaster. This would lead to a total rejection of advice to remain sheltered even for a minimum period. Alternatively, apathy on a mass scale might develop after the attack, once the scale of destruction became apparent and there were deaths in the family or family members failed to return. This would similarly result in failure to take whatever precautions were necessary for survival. Some survivors would show a 'fight' response, the effect of which is difficult to estimate. It could result in massive public unrest, aggressive behaviour towards any remaining forces of law and order, looting for food and attacks upon weaker survivors.

The unique additional feature of a nuclear attack, as opposed to other disasters, would be the existence of fallout. Within a large area down-wind of the explosion, fallout levels would be such that a lethal dose of radiation would be quickly accumulated by anyone who was not adequately sheltered. Those shelter facilities which exist for public use are either dilapidated Second World War shelters, unadapted tunnels such as the London Underground or a very few newly-constructed shelters in some public buildings. In practice, most of the survivors would have to find whatever shelter they could among the ruined and damaged buildings or risk death from radiation sickness. Those sheltering in areas that were heavily contaminated would be unable to break shelter for more than a very short time without risking themselves for up to 3 weeks. The conditions of these improvised shelters would be appalling and the number of casualties would be so high that there would be few without seriously injured and dying occupants.

Uncertainties about the level and extent of ionising radiation would be an additional source of anxiety leading to panic. It would be immensely difficult to provide sufficient equipment and personnel to measure prevailing levels of radioactivity and to relay whatever information was available to survivors.

There would be complete or major disruption of all lines of communication except perhaps wireless, though even this would be affected and many receivers inactivated by the electromagnetic pulse released by nuclear explosions, particularly those in the upper atmosphere.

Before long, physical hardships would add to the psychological distress, as shortages of food and drinking water became severe. Food stocks and food processing plants would be destroyed from the effects of blast, heat and fire; livestock would be killed and vegetable produce contaminated by irradiation; perishable food-stuffs would be lost, and distribution of the remaining food would be seriously compromised. Water supplies depend on electrically powered pumps and an extensive network of piping, both of which would be severely damaged, and the water in many reservoirs would be contaminated by fallout. Shortages of food and water would inevitably lead to outbreaks of violence in order to secure supplies. Policing would have to be very limited until radiation had dropped to a safe level. Under such conditions, those prepared to resort to violence would be most likely to survive.

**The Outcome**

The overall outcome of a nuclear war is almost as difficult to predict as it is to imagine. The idea that nuclear war, once begun, could be confined to a battle area is discounted by many military experts. If a major exchange of nuclear weapons were to occur the countries involved would soon contain large areas of complete devastation with few survivors; areas of serious damage out of which would emerge vast numbers of injured, irradiated and bewildered refugees; and areas of relatively light blast damage threatened by uncertain levels of radiation and the streams of refugees. Even with effective authority the numbers would be such that careful sorting of casualties would be out of the question. The use of force to prevent large numbers of injured people entering a hospital or first-aid station is an extremely unpleasant prospect but could be considered necessary.

Information about any other than immediate local conditions would be fragmentary, adding to the general state of unease and tension. Continued shortages of food, water and other necessities would add to these difficulties.

Effective policing would be hindered by such chaotic conditions and by the breakdown of social structures, the loss of confidence in authority likely in such circumstances and the depression and apathy characteristic of people bereaved of close relatives and familiar surroundings. The extent to which any surviving network of authority could begin to reconstruct organised life would depend upon its ability to control violent and bewildered crowds. Any person in authority would have to be prepared to kill to be effective. Later success would depend upon the cohesion of surviving networks of communication and remaining facilities.

Return to organised life would undoubtedly take many years after even the most limited of nuclear exchanges and would probably take several generations after a large-scale exchange. The social and cultural scars left by a nuclear war would be immense. Early death would become a far more common event.

Encouraged by the sense of apocalypse engendered by the war itself there would inevitably develop a much diminished respect for human life. Current medical practice in such matters as the care of the handicapped, the chronic sick and psychologically disturbed patients would have to be abandoned.

There would also be a great deterioration in public health standards. Epidemics would be facilitated by poor nutrition, debilitation due to injury or infection, reduced resistance to infection due to radiation, and an inadequate supply of vaccines and antibiotics. Vaccines could be less effective because of the effects of radiation. Insects, bacteria and viruses-which are relatively resistant to the effects of ionising radiation-would survive.

Sanitation, including not only the clearance of sewage but also the provision of clean drinking water, and the disposal of refuse and the dead would be seriously compromised. Diseases now under control would probably spread, including those caused by poor sanitation such as dysentery, infectious hepatitis and salmonellosis; diseases of overcrowding such as meningo-coccal meningitis, diphtheria and tuberculosis; and, in susceptible parts of the world, diseases of dirt and vermin such as typhus and even possibly plague. Common infections such as pneumonia and septicaemia that are at present readily treated with antibiotics could again become major killers. The impotence of contemporary medical knowledge deprived of its supporting technology and background public health measures is all too clear in some areas of the developing world.

In the longer term, the after-effects of a nuclear war might be worsened by damage to the atmosphere. It has been estimated that a full exchange of nuclear weapons between East and West would give rise to enough unstable oxides of nitrogen to reduce the thickness of the stratospheric ozone layer over the northern hemisphere by 30- 70% for 3 years. This would increase the penetration of ultraviolet and other harmful radiations from the sun, and also lead to heating of the upper atmosphere, which would disturb global weather conditions. A fall in average surface temperature by 1℃, which is possible in th ese circumstances, would be enough to seriously endanger wheat production in Western Canada. The penetration of ultraviolet radiation would lead to a large number of skin cancers and a considerable risk of severe sunburn even in temperate latitudes. Light-skinned animals such as pigs and Hereford cattle would be particularly at risk, as would certain crops such as peas and onions.
No reliable estimates have been made of the change in environmental ionising radiation that might occur after a full-scale nuclear exchange. Measurable changes have occurred since nuclear weapons testing began and the megatonnage exploded in tests is only a very small proportion of that available for war.

Table 9 gives some approximate estimates of the number of malignancies, abortions and genetic effects likely in the USA and the rest of the world after a full-scale nuclear attack upon the United States; these figures do not take into account the additional and more prolonged radiation likely after an attack on nuclear reactors. In addition, radioactive isotopes of long half-life would enter food chains and exert a variety of effects upon world ecology. Different species of plants and animals are sensitive to radiation by different degrees, and man is relatively sensitive. The long-term effects of radiation would continue to influence events for many years.

Table 10 Estimated effects of a full-scale nuclear attack on the United States

Within the US – millions

| | |
|---|---|
| Cancer deaths | 1 - 5 |
| Thyroid cancer (number of cases) | 1 - 2 |
| Abortions due to chromosomal damage | 0.15 - 6 |
| Other genetic effects (number of cases) | 0.4 - 9 |

Outside the US - millions

| | |
|---|---|
| Cancer deaths | 0.9 - 9 |
| Thyroid cancer (number of cases) | ~3.2 |
| Abortions due to chromosomal damage | 0.5 - 5 |
| Other genetic effects (number of cases) | 1.5 - 15 |

## ARE THERE GROUNDS FOR CONCERN?

The above description of the likely outcome of the use of nuclear weapons would be unnecessary and morbid if it were not for the fact that the risk of such a catastrophe appears to be increasing. Despite arms limitation treaties, the number of nuclear warheads continues to grow and an increasing number of countries have either already manufactured nuclear weapons or are developing the capacity to do so. The role of nuclear war in strategic planning has substantially changed recently and a reflection of this trend is found in the increase in civil defence recommendations and health service contingency plans.

The sophistication and complexity of nuclear weapons control systems that have developed over recent years adds to these risks and there now appears to be a real possibility that a nuclear war may begin in error.

It is often argued that the threat of a nuclear war has been the foundation of the preservation of peace in Europe since the Second World War. Deterrence in its simplest form is based upon the concept of 'mutually assured destruction' or MAD, whereby a state would not engage in an attack with nuclear weapons against another state possessing such weapons for fear of the level of damage resulting from a reprisal. In the 1990 Strategic Arms Reduction Treaty (START 1) the USA and Russia committed themselves to reducing their strategic nuclear weapons to 6000 warheads each. Under the 2002 Strategic Offensive Reductions Treaty (SORT) they agreed to reduce deployed warheads to between 1700 and 2000 each, but with no commitment to dismantle those withdrawn or any procedure for verification. There is currently no treaty, or prospect of one, restricting tactical (short-range) nuclear weapons.

According to the Bulletin of Atomic Scientists for 2006, the USA has about 10 000 warheads (5700 active, 4200 in reserve) with an explosive power of approximately 1200 megatonnes. Russia has about 16 000 warheads (5800 active, 10 000 in reserve) of explosive power 1900Mt. These amount to half a tonne of high explosive for every man, women and child today.
Nuclear weapons have been developed with different properties. They have been refined to make them more flexible in flight, this latter to facilitate the avoidance of detection by radar. These developments have put an additional strain upon warning and command systems. Once threatened by an approaching missile, a weapon has to be discharged before it is destroyed. Consequently warning systems have to rely upon increasingly sophisticated computerised systems for the rapid identification of, and response to, attack and additional psychological strains are imposed upon commanders. As the time between the detection of an attack and the launch of a reprisal becomes less, fewer opportunities remain for the critical assessment of the threat and a greater dependence upon electronic systems becomes inevitable. Highly sophisticated networks of warning systems and missile commands that threaten to remove virtually all human links are being developed. There have been several occasions already when a high level of alert has been ordered because of a computer error. It is not hard to imagine a situation in which the network of warning systems has become so sensitive and so complex that an exchange of nuclear weapons could occur simply as a result of a false signal.

## CONCLUSIONS

The Cold War is sometimes presented as an era that eventually reached some sort of stability due to the massive arsenals of the US and the former USSR and their shared fear of mutually assured destruction (MAD). It did in fact include times of terrible risk, first strike policies and grave distortion of information for public consumption. Eventually the dangerous stand-off shocked the world into reducing the nuclear threat through increased détente, the decommissioning of weapons, the Nuclear Non-Proliferation Treaty (NPT), and the Comprehensive Test Ban Treaty, which awaits entry into force. These Treaties today are under threat, both from the non-nuclear weapon states seeking to acquire nuclear weapons, but principally from the recognised nuclear weapon states seeking to evade their responsibilities under Article 6 of the NPT and developing new weapons.

The hypocrisy of the nuclear states leaves the non-nuclear states feeling increasingly vulnerable and in need of greater protection. A new arms race would bring with it all the dangers of the old: attempted justification for pre-emptive strikes, escalating retaliation scenarios, misinformation about the 'perceived enemy'. Blurring of the distinction between nuclear and non-nuclear weapons and a massive diversion of resources.

As health professionals we are aware that the continued possession of nuclear weapons and the development of new nuclear weapons is not only dangerous but a huge waste of resources. At a time when our National Health Service is acutely short of funds, for Britain to embark on a programme to develop a new nuclear weapon system to replace Trident, with capital costs of up to £25 billion and running costs of perhaps £50 billion more, would divert massive resources and potentially create death and sickness on a massive scale, would be totally irresponsible.

It is essential to begin realistic negotiations between all the actual and potential nuclear weapon states to bring about nuclear disarmament, as they are under an obligation to achieve under Article 6 of the NPT. The objective should be a Nuclear Weapons Convention, which would ban the production, stockpiling or use of nuclear weapons and require the destruction of existing stockpiles as do the Biological and Chemical Weapons Conventions for the respective weapons. A draft NWC drawn up by Costa Rica already exists as a United Nations document.

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## APPENDIX 1 – Relevant radiation physics

**Atomic structure**
An atom consists of a central nucleus containing protons and neutrons, surrounded by a cloud of electrons. The weight of a proton and neutron are approximately equal, but the weight of an electron is about 1,840 times less. Protons are positively charged, electrons have a negative charge of equal magnitude and neutrons are electrically neutral. An atom contains an equal number of protons and electrons in order to maintain electrical neutrality, and this is the atomic number.

All the atoms of one element contain the same number of protons and have the same atomic number. They may, however, have different numbers of neutrons so there may be more than one atomic species of the same element. These have different atomic weights and are known as isotopes of the element. Some isotopes are stable but some decay to a stable state with the emission of ionising radiation; these are properly referred to as radionuclides but commonly are called radioactive isotopes or radioisotopes.

**Types of radiation** from the decay of radioactive isotopes

a) Alpha particles: Two protons and two neutrons; identical with the nucleus of helium.
b) Beta particles: Electrons emitted from the nucleus on breakdown of a neutron, forming a proton at the same time.
c) Gamma-rays: Very short wavelength electromagnetic waves emitted during the disintegration of a nucleus.
d) Neutrons: One of the two fundamental building blocks of atomic nuclei.
e) Protons: The nucleus of the hydrogen atom and the other fundamental building block of atomic nuclei.
f) X -rays: Another form of electromagnetic radiation; generally of somewhat longer wavelength than gamma-rays.

**Effects of ionising radiation**
Alpha and beta particles have only a very limited range of penetration. Beta particles are capable of causing burns if in direct contact with skin. If isotopes emitting these particles gain entry into the body, both alpha and beta particles, but particularly the former, can produce intense local and harmful radiation. In comparison with alpha and beta particles, gamma-rays are highly penetrating. Neutrons can also be highly penetrating and may produce greater biological damage than equivalent amounts of gamma-rays as a result of secondary ionising radiation on interaction with other atoms.

**Radiation units (older)**
a) Curie (Ci) is a unit of radioactivity and is defined as $3.7 \times 10^{10}$ radioactive disintegrations per second.
b) Roentgen is a unit of exposure, and is the ability of the radiation to produce ionisation in air.
c) Rad is a unit of radiation dose and is the energy absorbed per unit mass. The conversion factor for roentgens to rads is of the order of one for gamma and beta radiation, but depends on the type of radiation, its energy, and the tissue exposed.
d) Rem stands for Roentgen Equivalent Man, and is the unit of dose equivalent or biological dose. It equals the dose multiplied by a quality factor (QF), which takes into account the greater effectiveness of some types of radiation in producing biological effects. The quality factor for gamma-rays and X-rays is, by definition, one. It is usually assumed, for radiation protection

purposes, that high-energy neutrons, which are emitted by a nuclear explosion, have a quality factor of 10.

**Radiation - SI units**
The international system (SI) units are now replacing the old units.
a) The SI unit of radioactivity is the becquerel (Bq) equal to one disintegration per second.
b) The SI unit of radiation dose is the gray (Gy); 1 gray equals 100 rads.
c) The SI unit of dose equivalent is the sievert (Sv); 1 Sievert equals 100 rems.

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## APPENDIX 2 - Some particularly important radionuclides in bomb fallout

| Radionuclide | Type of radiation | Half-life | Organ of Deposition | Particular Hazard* |
|---|---|---|---|---|
| iodine-131 | beta | 8.3 days | thyroid | thyroid cancer |
| hydrogen-3 (tritium) | beta | 12.3 years | whole body | effect on gonads |
| strontium-90 | beta | 29 years | bone | bone cancer, leukaemia |
| caesium-137 | beta, gamma | 30 years | whole body | effect on gonads |
| carbon-14 | beta | 5,730 years | whole body | effect on gonads |
| plutonium-239 | alpha | 24,400 years | bone, liver, lung | bone and lung cancer |

*depending upon dose and the chemical form in which isotope enters the body

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**REFERENCES**
Glasstone S and Dolan PJ (1977) *The Effects of Nuclear Weapons.* Castle Publishing Ltd Castle House, 27 London Road, Tunbridge Wells.
Home Office and Scottish Home and Health Department (1977) *Nuclear Weapons.* HMSO
Lewis KN (1979) *Prompt And Delayed Effects Of Nuclear War.* Scientific American, 241, 27-39.
United States Congress Office of Technology Assessment (1980) *The Effects of Nuclear War.* Croom Helm Ltd.

**FURTHER READING**

(A) GENERAL

Hersey J (1946) *Hiroshima.* Penguin Modern Classics.

Liebow A et al (1949) *Pathology Of The Atomic Bomb Casualties.* American Journal of Pathology, 25,853-860.

Lown B et al (1962) *The Medical Consequences Of Thermonuclear War* . New England Journal of Medicine 226, 1126 -1145.

Medact (2006) Britain's New Nuclear Weapons: Illegal, Indiscriminate and Catastrophic for Health.

(B) BLAST EFFECTS

Owen-Smith MS (1979) *Blast Injury.* Journal of the Royal Army Medical Corps, 125,4-16.

(C) RADIATION EFFECTS

Fetter SA and Tsipis K (1981) *Catastrophic Releases Of Radioactivity.* Scientific American, 224, 33-39.

Ishimaru T et al (1979) *Dose - Response Relationship Of Neutrons And Gamma-Rays To Leukaemia Among Atomic Bomb Survivors In Hiroshima And Nagasaki By Type Of Leukaemia 1950-1971.* Radiation Research, 77, 377- 394.

Rotblat J (1978) *Risks For Radiation Workers.* Bulletin of Atomic Scientists, 34, 41-46.

NUCLEAR WEAPONS

Aldridge RC (1977) *The Counterforce Syndrome: A Guide to US Nuclear Weapons and Strategic Doctrine.* Institute of Policy Studies.

Carson MJ (1976) *The Global Consequences Of Nuclear Weaponry.* Annual Review of Nuclear Science, 26,51-87.

SIPRI (1980) *World Armament and Disarmament. SIPRI Yearbook (1980).* Stockholm International Peace Research Institute.

UN (1980) *General and Complete Disarmament: Comprehensive Study of Nuclear Weapons.* United Nations General Assembly, 35th Session (1980). Item 48b. A/35/392.

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