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NAPC

HAZARDS OF A NUCLEAR WEAPON ACCIDENT

DEPARTMENT
OF
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RESTRICTED

NUCLEAR ACCIDENT PROCEDURES COURSE

THE HAZARDS OF A NUCLEAR WEAPON ACCIDENT

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1. GENERAL EFFECTS

1.1 Introduction

Because of the safety features it is impossible for a full nucler yield to occur if a weapon becomes involved in an accident or fire. The main hazards are therefore related to the HE and radioactive materials. The HE represents a major hazard to the initial response forces (including monitoring teams) whereas the dispersal of radioactive material represents a public health hazard.

2. EXPLOSIVE AND FIRE HAZARDS

2.1 High Explosive Hazards

The HE contained in nuclear weapons may explode due to impact or fire. An impact induced explosion will have occurred before fire fighters and rescue personnel arrive and will be a hazard to handling teams only. The HE hazard to fire fighters and rescue personnel is therefore directly related to explosion induced by fire, rough handling or abrasion after the accident.

The probability of explosion from fire decreases as the amount and confinement of HE exposed to fire is decreased. The time required to produce an explosion (if any) depends on the physical conditions of the weapon after impact, the characteristics of the weapon case or container, its location in relation to the seat of the fire, heat intensity and many other variables. The number of ways in which HE may burn means that it is impractical to try to distinguish it from the other burning materials in the fire.

The explosive hazards associated with the HE of nuclear weapons are similar to those associated with like quantities of other HE, or stored energy in fuel tanks or pressurised containers ie blast and fragmentation. It should be treated in the same way but always bearing in mind that it may result in the spread of radioactive contamination.

Other explosives are contained in nuclear weapons such as gram amounts in neutron generators and firing sets, cartridges for parachute drogues and spin rockets etc.

If a weapon case is ruptured, pieces of HE, some burning and some partly burned, may be scattered arond the accident area.

These pieces should not be stepped on, driven over, or disturbed in any way as they may be sensitive to shock or impact or from abrasion and should only be handled by experts although they may have to be handled by response teams. Unconfined pieces of HE usually burn without detonating or exploding.

2.2 Magazine Hazards

Should an accident involving one or more nuclear weapons occur in the magazine of a ship carrying a mixed outfit of weapons, additional dangers will face the response forces. In particular one could suggest dangers from the sympathetic detonation of other weapons such as depth charges or torpedo warheads and the fire, explosive and toxic hazards which would be encountered should Otto fuel become involved.

3. RADIOACTIVE MATERIAL HAZARDS

3.1 General Hazards

Nuclear weapons contain radioactive materials that may be hazardous in an accident or fire; for example plutonium and tritium. These materials may be dispersed if HE explodes or burning occurs, particularly with an explosion. This is because detonation pulverizes much of the nuclear material into particles small enough to be dispersed in the air. By comparison burning or oxidizing converts only a small fraction of the material into particles available for dispersion, but this can still form a hazardous cloud.

It is therefore essential that any fire is fought to prevent weapon explosion. The potential danger to fire fighters and initial response force personnel from the radioactive hazards can be reduced by using self-contained breathing apparatus or respirators, and protective clothing. If tritium is believed to be involved in an enclosed space then self-contained breathing apparatus must be used.

In general the radioactive materials in a nuclear weapon do not present an external hazard (ie, a dose of radiation to the body delivered from a source external to the body) but all the nuclides present a serious hazard once they have entered the body. Entry to the body can be made by inhalation, ingestion and through breaks in the skin.

3.2 The Hazards of Plutonium

Since plutonium is primarily an alpha emitter, we are usually concerned with it as an internal hazard. Being a heavy metal, plutonium also presents a toxic hazard similar to that associated with lead. The toxic effect is not considered to any extent when discussing the hazards associated with plutonium because of the magnitude of the radiation hazard and the fact that protection against the radiation hazard will amply guard against the toxic efect.

Plutonium will produce toxic effects primarily by the inhalation of vapours, fumes, or particules suspended in the atmosphere. Some small degree of absorption is also possible through the gastrointestinal (GI) tract and the skin. In most situations, absorption through the GI tract and the skin are considered negligible.

A large internal dose of plutonium can produce such symptoms as hallucinations, blindness, and optic neuritis. The kidneys are the organs most affected by heavy-metal poisoning. It must be emphasized, however, that an internal dose of plutonium large enough to produce the above effects will probably cause more serious and immediate effects due to the irradiation of living tissue by alphas particles.

In evaluating the radiation hazard associated with plutonium, and to simplify the topic, we generally consider only plutonium-239. It must be remembered that while plutonium-239 is extremely hazardous radiologically, there are other, less common, isotopes that can present even more severe hazards due to their greater activity. Generally speaking, the biological effects are similar regardless of the isotope considered.

The alpha particle emitted from plutonium-239, though fairly energetic, is not capable of passing through the dead layer of skin on the outer surface of the body. This means that plutonium that is external to the body presents no significant hazard as long as it remains external to the body.

Plutonium that is placed on the skin is not considered hazardous since absorption through the skin is negligible. Experimental evidence indicates that $10^{-3}\%$ of the insoluble oxide is absorbed via the gastro-intestinal tract into the blood stream; and this is considered to be a negligble amount. Plutonium intake through shallow wounds is also practically negligible. However, it should be noted that plutonium intake into the bloodstream by injection or by entry into deep wounds can be serious, although absorption into the system is slow. Normally, most plutonium can be removed from cuts and superficial wounds when the scab or surface crust is removed.

The primary hazard of plutonium results from entry into the body by inhalation. The actual amount of plutonium or plutonium oxide that is absorbed into the bloodstream through the lungs is quite important. It is extremely difficult to determine the fraction of inhaled plutonium that is absorbed into the bloodstream. The particule size is significantly important since smaller particles are more easily retained in the lungs and eventually absorbed.

The solubility of the material involved will affect its absorption characteristics. The particle density and the breathing rate of the individual involved are also very important. Although it is not always practical to determine and properly use all of these factors, some broad generalizations can be made as a result of animal experimentation. If a hundred particles of plutonium-239 of optimum size (1-10 μ) for retention in the lungs are inhaled, about 25 of these are immediately exhaled and 50 are deposited in the bronchial tree and are removed within a few hours or a few days by ciliary action and by swallowing. Of the 25 particles remaining in the lungs, only around 10 or less are actually absorbed into the bloodstream. The remaining 5 particles may be phagocytized (eg, ingested by cells), deposited in the lymph nodes, or pushed up into the bronchial tree and swallowed. It takes 150 to 200 days for these last 15 particles to be removed.

Most of the plutonium that enters the bloodstream is deposited in the bone and in the liver. A few months after exposure, 80 to 90 percent of the total body burden of plutonium will be found in the skeleton, where it appears to be absorbed in the surfaces of newly formed bone. Bone deposition may produce bone diseases (including cancer) many years later.

Once inside the body, plutonium-239 is eliminated extremly slowly eg plutonium deposited in the liver is assumed to be retained with a half-life of 20 years and plutonium deposited in the skeleton is assumed to be retained with a half-life of 50 years, based upon latest estimates (1987). This means that the absorbed plutonium, albeit decreasing is effectively held for a lifetime, and it can continue to emit alpha particles and cause damage wherever it is in the body. Large amounts of plutonium deposited in the body can produce immediate damaging effects which might cause death in a few months. Smaller doses, which are of course more likely, may result many years later in bone cancer, chronic anaemia, osteoporosis, and in bone necrosis which may produce spontaneous bone fractures. Such results may be expected 10, 20 or even 30 years after deposition, depending upon the size of the dose.

From information presented by the Internation Commission on Radiological Protection (ICRP) (in Publication ICRP 30) the annual limit on intake (ALI) for ^{239}Pu is set at 500 Bq. Based on standard (Reference) man data, this implies a limiting airborne concentration of 2×10^{-2} Bq m^{-3} assuming this concentration is inhaled over a 2000h working year. Higher values may be inhaled, however, over much shorter periods of time, provided the ALI is not exceeded.

Although bone and liver deposition is usually of primary interest, it should be noted that for short term exposures, the lungs are the organ of primary concern. During the period that plutonium remains in the lungs (about 500 days for the amount of plutonium to be eventually eliminated from the lungs), the lungs are irradiated and damage can occur. For longer exposures, bone deposition becomes the predominant condition affecting annual limits on intake.

The elimination of plutonium that is deposited in the body is a very slow process. It is indeed fortunate that some elimination does occur, since this provides a means of estimating the amount of plutonium a person has absorbed. Urinalysis for plutonium can thus be used to estimate the absorbed dose of an individual.

If a person is given prompt treatment with a chelating agent (such as DTPA, diethylene triaminepentaacetic acid), the biological half-life of the plutonium can be significantly decreased. This technique seems to add the possibility of kidney damage, however, so that a newer technique called lung lavage has been developed. In lung lavage the lungs are flushed with saline soon after a serious inhalation occurs, to remove inhaled plutonium directly before absorption from the lungs begins.

3.3 Disperal of Plutonium Following an Accident

Several factors affect the dispersal of plutonium following a weapon accident. Of these the most important are considered to be:

a. quantity of plutonium involved;
b. hight of cloud from which the plutonium is dispersed;
c. Pasquill stability characteristics;
d. wind velocity and direction; at various hights;
e. wind shear.

Taking each of these in turn:

a. Quantity of Pu - this may be estimated from the numbers and types of weapons involved. This information should be included in the accident report.

b. Height of Cloud - this is related to the quantity of explosive involved. This can be estimated from the numbers and types of weapons involved. This information should be included in the accident report.

c. Pasquill stability - this information should be included in the accident report.

d. and e. Wind - this information is unlikely to be available immediately for various heights. It may become available later in the evolution of the accident situation.

This information will enable an estimate to be made by AWRE computer of doses arising from both the external and internal radiation hazards as a function of range and bearing from the datum point. These doses are compared with Emergency Reference Levels (ERLs) of dose published by the National Radiological Protection Board (NRPB) from which derived Emergency Action Guidance Levels (EAGLs) are used following a Nuclear Weapon Accident (NWA).

The NRPB recommended lower level of dose to the whole body for evacuation is set at 0.1 Sv (10 rem) and the lower level of dose to a single organ for evacuation is set at 0.3 Sv (30 rem).

Based on the understanding in BR 4022 ground depositions of phutonium oxide, may be re-suspended and consequently inhaled giving rise to doses to the bone for these, EAGLs have been derived to meet the NRPB criteria as follows:

Ground Contamination Level	Evacuation
20,000 k Bq m^{-2}	Within 12 hours
2,000 k Bq m^{-2}	Within 7 days

These values assume no dust raising operations, nor the wearing of respirators.

3.4 Radiological Hazards of Tritium

Outside the body, tritium is not a severe biological hazard. Its weak beta particle has a maximum range in air of 7.3 milli-metres (mm) and cannot penetrate the skin. In its gaseous state, tritium is not absorbed by the skin to any significant degree; less than 0.1 pecent of the gas taken into the lungs is absorbed.

The hazardous nature of tritium is due to its ability to combine with other materials. Tritium water vapour (T_2O and HTO) is readily absorbed by the body; almost 100 percent of the inhaled water vapour is retained. In the water vapour form, tritium is also readily absorbed through the skin. In practice, a person exposed to a tritium atmosphere will receive approximately 50 percent of his tritium dose by inhalation; the other 50 percent will come from skin absorption. The radioactive water that enters the body is chemically identical to ordinary water and this is distributed throughout the body tissue.

Tritium which has plated out on a surface or combined chemically with solid materials is a contact hazard; that is, a person touching a contaminated surface will absorb some of the tritium through his skin. Again, the absorbed tritium will be distributed throughout the entire body. The human body normally eliminates and renews 50 percent of its water in about 14 days. This "turnover time" or "biological half-life" varies with the fluid intake. Since tritium oxide is in fact water, its residence time in the body may be significantly reduced by increasing the fluid intake. Under medical supervision, the biological half life may be reduced to about 3 days. Extreme caution should be exercised when significantly increasing the fluid intake, since an excess of body fluid may upset the electrolytic balance of the body and cause illness or death.

If forced-fluid treatment is deemed necessary and medical supervision is unavailable, a recommended procedure is to have the patient drink 1 quart of water within one-half hour after exposure. Thereafter, the volume of fluid excreted as urine is measured and an equal volume of water is drunk. Medical assistance should be obtained as soon as possible.

Although the biological half-life of tritiated water is short, the ease with which it is absorbed and its high specific activity, together with its distribution throughout the body tissue, combine to form a severe biological hazard. The ICRP recommended ALI for tritiated water (^3H_2O) is 3×10^9 Bq, corresponding to an airborne concentration of 8×10^5 Bq m^{-3} (40h week, 50 week year). Protection against the hazard is limited. Impervious protective clothing and the use of self-contained breathing apparatus will protect personnel for short periods of time, but after 2 to 3 hours tritium may diffuse through.

4. TOXIC HAZARDS

4.1 Beryllium Hazards

As with many other hazardous materials, inhalation is the most significant means of entry into the body. Beryllium itself will oxidize easily; and therefore any fire or explosion involving the element is almost certain to liberate hazardous fumes and smoke. It should also be recognized that powders, dusts, and shavings resulting from machining operations are extremely hazardous.

Absorption through the skin is more important with beryllium than with many other hazardous materials. When beryllium contaminates cuts, scratches or abrasions on the skin, ulceration often results. The lesions formed heal very slowly and sometimes become chronic. It is also possible to absorb some compounds through the intact skin.

One of the peculiarities of beryllium poisoning is that there are no symptoms which are specific for beryllium intoxication. The most common symptom is an acute or delayed type of pneumonitis (berylliosis). Other commonly occurring signs and symptoms are ulceration and irritation of the skin, shortness of breath, chronic cough, cyanosis, loss of weight, and extreme nervousness. Following exposure, there can be a long latent period varying from 3 months to as much as 5 years.

In the acute form of berylliosis, death or full recovery will normally occur within a period of something less than year. However, with the delayed (chronic) form of berylliosis, progressive disability will generally occur. The respiratory tract will become increasingly congested, and the individual concerned will become increasingly more disabled. Such a condition may gradually worsen for many years, until death finally results. Although cortizone and some steroids have been successfully employed to slow this progressive disablement, no actual cure for berylliosis is known.

Beryllium or its compounds, when in finely divided form, should never be handled with bare hands but always with rubber gloves. Some type of efficient dust respirator and anti-contamination clothing must always be worn in an area known (or suspected) to be contaminated with beryllium dust. A self-contained breathing apparatus is neccssary whenever beryllium fumes or smoke is present.

Decontamination of personnel must be carried out in a manner similar to that for plutonium and must be just as thorough.

Decontamination of terrain or facilities will be similar to radiological decontamination. The best method, when applicable, is vacuum cleaning.

Since it is not radioactive, the detection of beryllium in the field is impractical. Therefore, any determination of the presence of the metal must be referred to a laboratory with the necessary equipment. An analytical procedure can be performed on urine if internal deposition is suspected. Essentially, the analytical procedure consists of chemically isolating the beryllium which is then mixed with a compound that results in fluorescence to a degree determined by the amount of beryllium present. The intensity of the fluorescence is then measured on a fluorophotemeter.

4.2 Lithium Hazards

Lithium can react directly with water in body tissues, causing severe chemical burns.

Lithium hydroxide is also a caustic agent which affects the body in the same manner as lye (sodium or potassium hydroxide).

Respiratory protection and protective clothing are necessary to adequately protect personnel exposed to fires involving lithium or lithium hydrides.

DOSE TO WHOLE BODY Vs DISTANCE

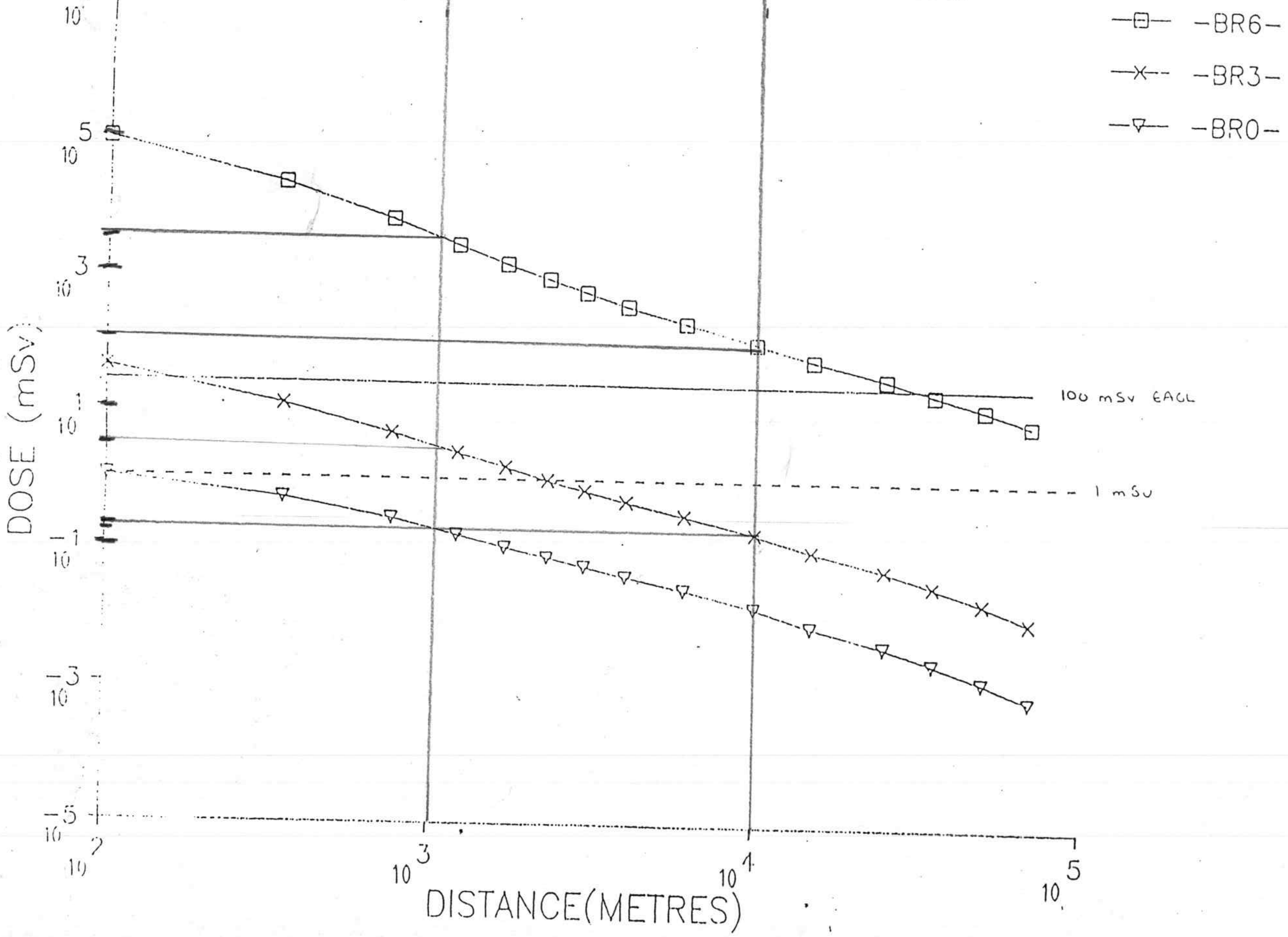

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FIG 2