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## 2 Introduction

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### 2.1 GENERAL FRAMEWORK

#### 2.1.1 Origin of SCOPE-RADTEST

From 1988 to 1991 SCOPE carried out a project 'Biogeochemical Pathways of Artificial Radionuclides' (RADPATH), which was successfully concluded with the publication of SCOPE 50, *Radioecology after Chernobyl* (Warner and Harrison, 1993). Taking note that the scientific potential of the project had not been fully exhausted, experts at the RADPATH Scientific Advisory Committee Meeting and at the 5th Conference 'Geochemical Pathways of Artificial Radionuclides in the Biosphere' (Puschino, Commonwealth of Independent States, 1991) recommended that SCOPE continued activities in this field.

This proposal was discussed at the 8th SCOPE General Assembly (Seville, Spain, January 1992) and the idea of a new project organization was supported. In May 1992, Professor Charles Shapiro (USA) met with experts in China representing SCOPE's China National Committee and the China RADPATH Committee, which represented 24 institutions within China. These meetings resulted in a statement of agreement that expressed the interest and enthusiasm of China for participation in the proposed study.

On the initiative of Professor Shapiro and the Russian National SCOPE Committee, a meeting of a group of experts from Russia, USA and China was organized in Moscow, 5–7 November 1992; twenty experts attended this meeting. At this meeting, it was decided to narrow the focus of the study to fallout from nuclear tests. A memorandum of understanding was drafted on the organization of a new SCOPE project 'RADTEST' (RADIation from nuclear TEST explosions).

In April 1993, the SCOPE Executive Committee meeting in Paris formally adopted RADTEST as an official SCOPE project. The RADTEST project was established initially within SCOPE's Biogeochemical Cycles Cluster, and subsequently within its Health and Environment Cluster, following a reorganization within SCOPE. In order to conduct the project, a RADTEST Steering Committee (with international members) was appointed, under the chairmanship of



Professor Sir Frederick Warner, and a central Secretariat was established at the University of Essex, UK, to assist with obtaining and disseminating information relating to the project.

### 2.1.2 Project objectives

The RADTEST project has been involved in examining the transport, deposition and human health effects of radioactive fallout from nuclear weapons tests through international, collaborative study. The involvement of countries such as Russia, USA, China, France and UK and of other international bodies was achieved, including participation of nuclear scientists who were directly or indirectly involved with nuclear testing. Consequently the project has enabled previously restricted work, including data, models and knowledge about the fate of the release of radionuclides and their possible human health effects, to be discussed and considered for the first time.

An important objective of RADTEST relates to 'bridge building'. One cannot underestimate the potential importance of effective communication and collaboration of scientists who have been involved in studies of the radioactive fallout from nuclear tests. These communities of scientists, heretofore isolated from each other, can establish working relations, collaboration, and trust with each other. This can greatly facilitate scientific consensus, which is necessary in reaching and carrying out agreements at the political level. Such 'bridge building' truly is in the spirit of SCOPE.

RADTEST has focused on the following principal tasks.

1. Updating the inventory of relevant nuclear tests.
2. Establishing an inventory of data on measurements of radionuclide deposition densities and identifying gaps in these data.
3. Comparison of old and, when needed, development of new models of radioactive transport to better understand the deposition densities of radionuclides, both on and near the nuclear test sites, including areas downwind where potentially significant episodes of fallout have occurred (such as the Altai region of Russia).
4. Study of the migration of radionuclides through the biosphere, including all pathways to humans, and the study of the effects on other biota that have impacts on humans, the main focus being the characterization of the nature and magnitude of the dose to humans. This includes dose reconstructions from past events, and also an increased capability for dose prediction from possible future accidental or deliberate explosions.
5. Analysis of the data on effects of these doses (including low doses) on human health.

In order to achieve the project's objectives, RADTEST organized a continuing programme of meetings, information dissemination and coordination activities.

The series of RADTEST workshops commenced with the North Atlantic Treaty Organization (NATO) Advanced Research Workshop (ARW) held in Vienna, Austria (10–14 January 1994). This ARW examined the Environmental and Human Consequences of Atmospheric Nuclear Tests. The second NATO ARW for the RADTEST project was convened in Siberia (5–10 September 1994) and related predominantly to the radioactive fallout in the Altai region of Russia, emanating primarily from nuclear tests undertaken at the Semipalatinsk test site in Kazakhstan. These meetings are reported in detail in section 2.3 and input to them formed the basis for two separate publications (Shapiro, 1998; Shapiro *et al.*, 1998).

A third RADTEST Meeting was held in Brussels/Liège (March, 1995) to examine environmental consequences of local radioactive fallout from nuclear test explosions and the associated health consequences and epidemiology for the exposed population. A final Mini-workshop was held in Beijing, China (19–20 and 23 October, 1996) in order to receive Chinese and French contributions and preliminary manuscripts to enable a synthesis of the project's findings to be prepared.

A series of *ad hoc* meetings was convened during the period between the Belgian and Chinese meetings, in order to advance the synthesis summarizing the findings of the programme. These included informal discussion meetings held in Minsk, Belarus (March 1996) and editorial meetings in Vienna, Austria (April and June 1996). A meeting of Senior Editors was held in Essex, UK (February 1997) to advance the finalization of this synthesis publication.

### 2.1.3 Logic flow

After summarizing the overall findings of the RADTEST project in the Synthesis (Chapter 1), this volume then examines the background to its establishment, its objectives and how these have been achieved, including issues relating to general concepts. Following a detailed examination of the sites and tests which have been carried out, the volume goes on to examine the environmental effects, including exposure pathways. A consideration of the estimation of doses leads on to a discussion about human health effects.

A key feature of the volume is the comprehensive listing of all tests which have led to releases (including vented underground tests). Finally, the volume examines the conclusions, and recommendations, which may be drawn from the study.

## 2.2 FROM THE FIREBALL TO HUMAN EXPOSURE

During a nuclear explosion, the fission products, residual fissile material and structural materials associated with the device are raised to sufficiently high

temperatures to be present in gaseous form. For explosions detonated in the atmosphere near the surface of the Earth, a considerable amount of volatilized soil or rock material may also be entrained in the fireball (UNSCEAR, 1977a). Some activation products are also generated by neutrons. After an explosion in the atmosphere, the fireball expands rapidly and rises due to buoyancy. As it rises, cooling causes the volatilized debris to condense, forming an aerosol with a wide distribution in particle size. The radioactivity that falls out of the cloud after the explosion is called the radioactive fallout. In the ordinary atomic bomb, for example, for each 20 kt of TNT equivalent of explosive energy, about 1 kg of radioactive material is produced. In this 1 kg of radioactive material are some 90 different radionuclides varying in lifetime from a fraction of a second to many years. This mixture of radioactivity decreases in such a way that for every sevenfold increase in age, the total radioactivity is decreased tenfold (Libby, 1956a). As the inventory of radioactivity produced by the fission reaction changes its characteristics continuously and rapidly after the bomb detonation, the firing conditions are of prime importance in determining the fallout quality and effects.

Many radionuclides present in fallout emit gamma rays and contribute to the dose from external irradiation. The most important from this point of view are a number of short-lived radionuclides, the most significant of which are  $^{95}\text{Zr}$  and its daughter  $^{95}\text{Nb}$ , and the long-lived  $^{137}\text{Cs}$  (UNSCEAR, 1977b). As the time required for ingestion into the body is long, ingestion is unlikely for the shorter-lived fission products, and therefore the principal hazards for close-in fallout are radiation exposures by gamma radiation of the whole body, and by beta radiation on the skin. Over longer times, weeks and months after the explosion, the ingestive hazards begin to become important (Libby, 1956b), see Figure 4.1.

A bomb fired on the surface of the Earth, however, may have an appreciable portion of its radioactivity settled within relatively short distances, whereas bombs fired beneath the surface of the Earth may place essentially no fallout radioactivity in the atmosphere. Therefore, the question of the area of contamination to be expected from nuclear weapons cannot be answered categorically without specifying the degree of contact of the fireball with the surface of the Earth, and probably also specifying the characteristics of this surface. For weapons fired on the surface, the activation of the surface materials is a possibility, but in general it appears that most of the neutrons form stable isotopes and that the amount of radioactivity produced, at least with ordinary surface materials, is relatively small. The principal radioactive products of nuclear weapons are produced in the weapons themselves, and not in the environment (Libby, 1956a).

A consequence of the presence of radionuclides in the environment is the potential for increased radiation exposure of living organisms. The impact of radionuclide releases on organisms may be assessed by consideration of the

likelihood and extent of radiation exposure and potential consequential effects (i.e. radiobiological response).

One must also consider the beta doses, which were estimated to be approximately eight times higher than gamma doses, although the depth of penetration of beta radiation as an external dose is very limited. For humans, external beta dose can cause skin burns (as in the Marshallese and Lucky Dragon episodes), but does not give a whole-body dose comparable to gamma rays.

### 2.3 NATO ADVANCED SCIENCE INSTITUTES

In the course of the RADTEST programme, two North Atlantic Treaty Organization (NATO) Advanced Research Workshops (ARWs) were held in Vienna, Austria (January 1994) and in Barnaul, Siberia (September 1994). These workshops were convened to examine the 'Environmental and Human Consequences of Atmospheric Nuclear Tests' and the 'Long-term Consequences of Nuclear Tests for Environmental and Population Health', respectively. The latter had a particular focus on nuclear tests undertaken at the Semipalatinsk Test Site in the Altai region of Russia.

The complete findings of these ARWs are now published in NATO's ASI series (Shapiro, 1998; Shapiro *et al.*, 1998), however, a brief summary of some of the issues addressed is provided below.

#### 2.3.1 Vienna advanced research workshop

The Vienna ARW examined the results of previous studies undertaken in the former Soviet Union, USA, UK and China.

The Russian studies were related to five principal areas comprising: the source term; modelling and dose reconstruction; environmental data; epidemiology and inventories at sites; tests and explosions. Valuable information concerning nuclear detonations at the Semipalatinsk and Novaya Zemlya test sites was obtained, in addition to information relating to world-wide test sites from the Soviet Radiation Monitoring Network (Ryaboshapko *et al.*, 1998).

The USA studies concerned the Off-site Radiation Exposure Review Project (ORERP) and events at the Nevada Test Site (NTS) and Marshall Islands. Church *et al.* (1990) give an overview of ORERP, which assumes the existence of a relationship between the external exposure and the deposition of radionuclides that enables dose reconstruction at the time of the tests. The total collective dose in the PHASE I area (parts of Nevada, Southern Utah and Arizona) is calculated as 58 000 person-rem (580 person-Sv), whereas in the PHASE II area, which includes all of Utah (including Salt Lake City), the total collective dose is 1 200 000 person-rem (12 000 person-Sv).

Contemporary data, which have recently become declassified, have provided the basis for overviews of the USA atmospheric tests at the Nevada Test Site (NTS), and at the Marshall Islands Test Site. It is expected that these data will be revised upon the declassification of further data. The Marshall Islands Radioecology and Dose Reconstruction Project has concentrated on the dose received at the time of the tests and to native islanders upon return to their homes.

As a consequence of detonations in Australia the potential radiological impact of residual contamination in the Maralinga and Emu Areas of Southern Australia has been studied, in addition to the mortality and cancer incidence in participants of nuclear weapons tests and experimental programmes. However, participants in such programmes show no detectable effect on their life-expectancy or on their risk of developing cancer or other fatal diseases (Darby *et al.*, 1993).

There have been studies in China to investigate nuclear cloud movement and to survey radioactive fallout due to nuclear tests (Yi *et al.*, 1998). The Chinese Ministry of Public Health has established a nationwide environmental radioactivity monitoring and investigation network to evaluate the impact of radioactive contamination from nuclear fallout and related health issues.

### 2.3.2 Barnaul advanced research workshop

An important issue addressed is dose reconstruction, where there appear to be important differences in the proportion of dose from external, inhalation and ingestion pathways. Much information has been gathered on medical-biological consequences of radiation impacts, and a summary of Altai's medico-ecological situation is given by Shoikhet *et al.* (1994). Their findings reveal a need to improve our understanding of the radiobiological situation there.

The radiological risk for the Altai region, due to nuclear tests at the Semipalatinsk site, has been examined by Algazin *et al.* (1994), revealing that the 29 August 1949 test contributed around 32 000 person-Sv (about 90% of the total collective dose in the region).

Stegnar (1994) reports that the International Atomic Energy Agency's (IAEA) preliminary conclusions from their assessment of the present radiological situation indicates that the dose to those living in surrounding settlements is unlikely to exceed  $50 \mu\text{Sv y}^{-1}$  (including a fraction due to general weapons fallout) from artificial radionuclides, which represents only a small percentage of the exposure from natural radioactivity sources.

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