

REAC/TS Radiation Accident Registry: Update of Accidents in the United States

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ABSTRACT

Serious injury due to ionizing radiation is a rare occurrence. From 1944 to the present, 243 US accidents meeting dose criteria for classification as serious are documented in the REAC/TS Registry. Thirty individuals have lost their lives in radiation accidents in the United States. The Registry is part of the overall REAC/TS program providing 24-hour direct or consultative assistance regarding medical and health physics problems associated with radiation accidents in local, national, and international incidents. The REAC/TS Registry serves as a repository of medically important information documenting the consequences of these accidents. Registry data are gathered from various sources. These include reports from the World Health Organization (WHO), International Atomic Energy Agency (IAEA), US Nuclear Regulatory Commission (US NRC), state radiological health departments, medical/ health physics literature, personal communication, the Internet, and most frequently, from calls for medical assistance to REAC/TS, as part of our 24-hour medical assistance program. The REAC/TS Registry for documentation of radiation accidents serves several useful purposes: 1) weaknesses in design, safety practices, training or control can be identified, and trends noted; 2) information regarding the medical consequences of injuries and the efficacy of treatment protocols is available to the treating physician; and 3) Registry case studies serve as valuable teaching tools. This presentation will review and summarize data on the US radiation accidents including their classification by device, accident circumstances, and frequency by respective states. Data regarding accidents with fatal outcomes will be reviewed. The inclusion of Registry data in the IAEA's International Reporting System of Radiation Events (RADEV) will also be discussed.

INTRODUCTION

Serious injury due to ionizing radiation is a rare occurrence. From 1944 to December 1999, through years of research, development, and use of nuclear materials in industry, energy production and medicine, only 30 people have lost their lives in 13 separate radiation accidents in the United States (Table 1). Information about these and 230 other less serious US accidents is documented in the US Radiation Accident Registry, maintained at the Radiation Emergency Assistance Center/Training Site (REAC/TS) in Oak Ridge, Tennessee.

REAC/TS was established in 1975 and is operated by the Oak Ridge Institute for Science and Education (ORISE) in Oak Ridge, Tennessee for the US Department of Energy. The REAC/TS program provides 24-hour direct or consultative assistance regarding medical and health physics problems associated with radiation accidents in local, national and international incidents. The REAC/TS facility serves not only as a treatment facility, but also as a central training and demonstration unit where US and foreign medical, nursing, paramedical, and health physics personnel receive intense training in medical management of radiation accidents.

One of the objectives of the REAC/TS program has been to broaden knowledge of the early and late effects of radiation injury in humans, with the goal of developing better diagnostic, therapeutic and prognostic modalities. REAC/TS maintains registries to further this aim through preservation of valuable historical and medical records for use in research and medical and health physics training. Medical aspects and subsequent follow-up of many serious accidents are reviewed in a series of conference proceedings on the Medical Basis for Radiation Accident Preparedness (1980, 1990, 1991).

THE REAC/TS RADIATION ACCIDENT REGISTRIES

The REAC/TS Registries include the Worldwide Accident Registry, comprising the US Radiation Accident Registry and the Non-US Accident Registry. Table 2 indicates the Registries maintained at REAC/TS and their status on December 31, 1999.

Information for the REAC/TS Accident Registries is gathered from many sources. These include reports from the World Health Organization (WHO), International Atomic Energy Agency (IAEA), Nuclear Regulatory Commission (NRC), state radiological health departments, medical and health physics literature, personal communications, the Internet, and, most frequently, from physicians, health physicists, and other involved individuals who call REAC/TS for assistance when an incident occurs.

REAC/TS takes an average of 55 calls for assistance each year. Although each of these calls is about a real or perceived event involving ionizing radiation, not all "incidents" involve significant exposures. For purposes of the Registry, designation as a "significant exposure"

requires the following conditions and dose criteria: 250 mSv (25,000 mrem) to the bone marrow of the whole body or to the gonads; 6,000 mSv (600,000 mrem) to the skin of the extremities; 750 mSv (75,000 mrem) to organs such as the eye or thyroid; internal contamination levels exceeding one half of the maximum permissible body burden (currently under revision); and medical misadministrations resulting in any one or more of these conditions. Significant “accidental ionizing radiation exposures” are defined as levels at which early biological changes and clinical symptoms might be detected.

Most calls for assistance to REAC/TS are concerned with one or more individuals who, through history, diagnostic testing, and/or dose estimation are shown to have had little or no exposure. Information about these “incidents” is maintained, but the “incident” is not counted as an “accident” for inclusion in the Registry. Examples of such incidents include:

- Discovery of a radium therapy source that had been in a file cabinet in a busy city office environment over a period of many years.
- Low level contamination in a residence that occurred when a discarded exit sign containing tritium (^3H) was brought home and broken.
- Unexplained exposure recorded by dosimeter (film badge, TLD).

Approximately one in five calls for REAC/TS assistance involves significant radiation exposure to one or more persons. Information about these “accidents” is recorded in the Registry. Every person who received any radiation exposure in the accident is listed in the Registry as “involved.” All such information is handled with discretion, under strict considerations for privacy, protection of human subjects, and other legal and ethical concerns.

The US Registry contains records from 243 accidents involving 1342 persons, including 790 whose exposures met the criteria for inclusion in the Registry. There is good reason to believe this number does not represent all radiation accidents in the US. Some accidents are unreported because of legal or financial concerns, lack of knowledge of radiation hazards or radiation effects, or because unsuspecting persons were unaware of an exposure.

US ACCIDENT EXPERIENCE

Accidents have been reported in 41 states, the District of Columbia, and Puerto Rico, with the greatest number of accidents involving radiation devices. These devices included sealed sources used in industrial radiography, radiotherapy, and industrial processes, x-ray generating devices used in medicine, research and industrial processes and quality assurance, and accelerators used in medicine and research. Table 3 lists the number of accidents by state, and Table 4 the major accidents in the US classified by the type of device involved in the accident.

One hundred and thirty-seven of the recorded accidents took place in industrial settings, with sources used in industrial radiography accounting for 51 accidents. There was a marked decrease in the number of industrial radiography accidents in the early 90s. Equipment changes, training, and regulations contributed to this drop, along with a reduced need for radiography of high pressure pipe welds, valves, and vessels (i.e. less construction of nuclear power plants, oil refineries, etc.). Ten accidents occurred in irradiation facilities. Forty-four accidents happened in industrial research and development. Other industrial uses accounted for 32 accidents.

Eleven individuals were injured by neutron and gamma exposures in criticality accidents during activities in nuclear weapons research and development, reactor engineering development, or production of enriched uranium. No one in the US has received a significant exposure in a criticality accident since 1962.

The greatest number of accidental deaths and significant exposures were associated with diagnostic or therapeutic procedures in medical facilities. The Registry (1944 to December 1999) includes information from 80 accidents in US medical facilities. One of these accidents alone accounts for 403 of the 790 individuals with significant exposures in the US. Seven accidents involved the use of x-ray devices in medical facilities; these resulted in significant exposures to 12 individuals. Thirty accidents occurred with sealed sources of radioactive materials, with 617 individuals involved, 457 significantly exposed and 11 deaths. Thirty-eight of the recorded accidents occurred with use of radiopharmaceuticals. These involved 112 persons, with 46 having significant exposures and eight deaths. There were five accidents with accelerators used in radiation therapy. As a result of these accidents, three persons lost their lives and two were seriously injured. These accidents in hospitals and other medical facilities occurred because of classical errors: wrong patient, wrong dosage (for example, mistaking “milli” for “micro”), wrong medication or because of irradiation of the wrong area of the body. Other errors resulting in injury or death included failure to determine if a female was pregnant or nursing, incorrect calibration of therapy devices, incorrect computer programming, errors in equipment maintenance or repair, negligence, and malpractice. Registry information about these and other cases is occasionally sketchy, incomplete, or not made available to REAC/TS, probably because of legal considerations.

Valuable information about several medical cases can be found in published works. For example, Flynn describes a case involving a 3.7 curie (136.9 GBq) iridium-192 brachytherapy source that was left in a patient for

92.75 hours, resulting in death of the patient and involvement of 95 persons (Flynn, 1993). Newman (Newman, 1990) describes deaths and serious injuries due to errors in the computer programming of a therapy device. Shope (Shope, 1995) describes serious skin injuries caused by prolonged periods of fluoroscopy.

The most common type of radiation injury in the US has been a local injury to some part of the body. Seventy-seven percent of all documented local injuries involved the fingers and hands. Another 6% were extremity injuries involving the arms, legs, or feet. Nine percent of local injuries involved the head or neck, and the remainder were injuries to the thorax and other areas. The radiation sources in these cases of local injury were predominantly sealed sources of iridium-192 and cobalt-60.

Accidents resulting in significant exposures due to internally deposited radioactive materials occurred in research and development activities, in industry, and, most frequently, in hospitals. Forty-three individuals given Iodine-131 or 125 had significant exposures. Two of these accidents involved pregnant women and another involved a nursing mother. Other radionuclides implicated in injuries and deaths include yttrium-90, plutonium and americium compounds, phosphorus-32, uranium compounds, gold-198, strontium-90, and mixed fission products.

THE IAEA INTERNATIONAL REPORTING SYSTEM

In 1994, the International Atomic Energy Agency (IAEA) convened Technical Committee TCM 850 on "A reporting system to collection information on accidents with radiation sources and devices, establish a repository database, and disseminate the information to member states." The meeting was organized in response to increasing concern at the rate of radiological accidents in industry and medicine, both in developed and developing countries. For some years the Agency had compiled brief notes of events which came to its attention. However, officers of the Agency, competent authorities of some member states, and some international professional organizations were considering the establishment of more formal systems for collection and dissemination among member states of information on unusual radiological events which could be of great practical value in encouraging a safer use of ionizing radiation. The technical committee was invited to make recommendations on how this could be achieved.

The technical committee recommended the establishment of a formalized system for reporting unusual radiological events (including near misses) to which member states can readily give support. In order to achieve this optimally, the technical committee recommended that the Agency establish a database to receive reports consisting of a minimum data set and a narrative describing the event in a form suitable for circulation. Competent authorities of member states would be invited to contribute to these reports. A draft database questionnaire was developed during the technical committee meeting.

Over the next four and one-half years, Agency personnel, and their consultants, worked on revision of the database questionnaire and decided on a Microsoft Access 97 format.

In early 1999, the Agency renamed the database the International Reporting System of Radiation Events (RADEV) and developed a draft TECDOC. A decision was also made to develop two separate data questionnaires for gathering information, one of these questionnaires would be related to exposure to members of the general public and radiation workers, while the second questionnaire would be related to overexposure to patients in a medical environment.

To test the medical component of RADEV separate medical questionnaires were completed based on overexposures in a medical environment from selected case histories contained in the REAC/TS Registry system. Questionnaires related to non-medical overexposures were completed based on information from other accident registries.

The development of RADEV has the potential to serve as a useful mechanism for reducing serious radiation accidents on a worldwide basis. With the cooperation of member states, this database can identify the causes and consequences of radiation overexposures, some serious to patients, radiation workers, and members of the general public.

SUMMARY

Serious radiation accidents in the United States have been rare. The safety record, unmatched by other technologies, is due in large part to careful regulation and control provided by regulatory agencies and radiation protection specialists (medical and health physics professionals). Although not all accidents result in injury, a serious radiation injury can be physically, psychologically, and economically debilitating to an individual; treatment is complex and prolonged and the outcome may not be satisfactory. Control, strict safety precautions, and training are absolutely essential elements in prevention of injuries. In these regards, the REAC/TS Registry for documentation of accidents serves useful purposes: 1) weaknesses in design, safety practices, training or control can be identified, and trends noted; 2) information regarding the medical consequences of injuries and the efficacy of treatment protocols is available to the treating physician; and 3) Registry case studies serve as valuable teaching tools.

To contact REAC/TS for consultation or to notify REAC/TS regarding an accident, call 865 576-3131 or 865 576-1005.

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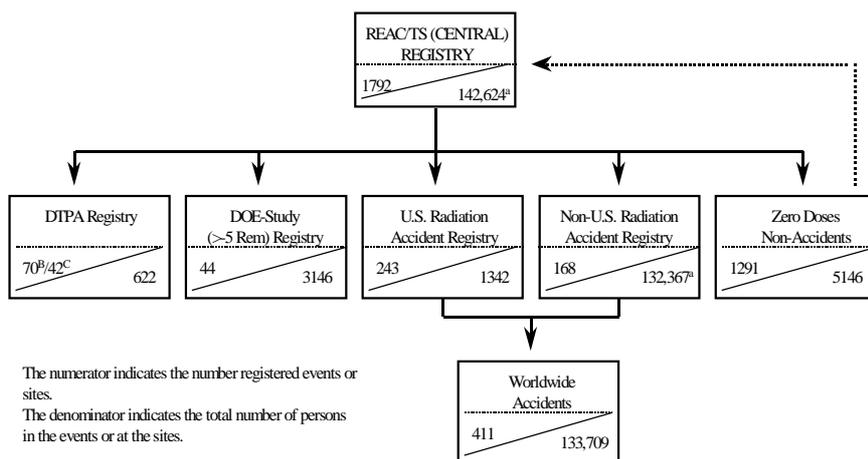
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State	Number of Deaths	Accident Circumstances
Idaho	3	Trauma/reactor criticality (non-radiation death)
New Mexico	3	2 – Research with critical assembly 1 – Chemical operations/criticality
Ohio	10	Radiation therapy
Oklahoma	1	Self-inflicted injury (probable)
Pennsylvania	1	Radiation therapy (brachytherapy)
Rhode Island	1	Chemical operations/criticality
Texas	9	7 – Nuclear medicine therapy 2 – Radiation therapy/computer programming
Washington	1	Radiation therapy (non-radiation death)
Wisconsin	1	Nuclear medicine therapy

Table 1: US Radiation Accidents Resulting in Deaths (1944-December 1999)

STATUS OF REAC/T S REGISTRIES

December 1999



The numerator indicates the number registered events or sites.
The denominator indicates the total number of persons in the events or at the sites.

- a. Includes Chernobyl - 116,500; Brazil - 249; Mexico - 4,000 Kyshtym - 10,180; Spain - 27
- b. Former and current DTPA sites
- c. Current co-investigators
- d. Worldwide

Source: Radiation Emergency Assistance Center/Training Site
Radiation Accident Registries

ORISE-RERDA-REACTS

Table 2: Status of REAC/TS Registries

State	No. of Accidents	State	No. of Accidents
Alabama	1	Montana	1
Alaska	0	Nebraska	0
Arizona	2	Nevada	4
Arkansas	0	New Hampshire	0
California	16	New Jersey	12
Colorado	2	New Mexico	10
Connecticut	4	New York	10
Delaware	0	North Carolina	1
District of Columbia	3	North Dakota	0
Florida	1	Ohio	8
Georgia	4	Oklahoma	4
Hawaii	3	Oregon	2
Idaho	3	Pennsylvania	16
Illinois	12	Rhode Island	1
Indiana	9	South Carolina	2
Iowa	2	South Dakota	0
Kansas	2	Tennessee	9
Kentucky	1	Texas	30
Louisiana	6	Utah	1
Maine	1	Vermont	0
Maryland	6	Virginia	3
Massachusetts	7	Washington	9
Michigan	7	West Virginia	0
Minnesota	5	Wisconsin	6
Mississippi	2	Wyoming	1
Missouri	1	Unknown	11
Puerto Rico	3		

Table 3: Number of Accidents in Registry by State
(Including the District of Columbia and Puerto Rico)

Classification	Number of Accidents	Number of Persons Involved	Number of Persons with Significant Exposure
Criticalities	11		
Critical Assemblies	4	74	19
Reactors	2	14	5
Chemical Operations	5	61	18
Radiation Devices	161		
Sealed Sources	110	848	578
X-ray Devices	38	58	55
Accelerators	12	15	14
Radon Generators	1	9	6
Radioisotopes	71		
Transuranics	23	110	25
Fission Products	7	31	19
Diagnosis and Therapy	38	117	48
Other	3	7	4
TOTAL	243	1342	790

Table 4: Major Radiation Accidents in the US
(1944 – December 1999)