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Relevance of Nuclear Weapons Clean-up Experience to Dirty Bomb Response

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During the past 50 years, the United States has experienced 32 major nuclear weapons accidents, nine of which released special nuclear material to the environment.[1] Response to these accidents, coupled with recovery experience following the Russian satellite reentry and weapons test site cleanup, form the basis for determining actions that might be required following a nuclear terrorist event involving the release of radioactive material. Though valuable information has been gained following the recovery from various commercial accidents, most notably the Chernobyl nuclear power plant failure and the dismantled radiography source in the Brazilian city of Goi nia, this paper will focus on the lessons learned from the U.S. nuclear weapons program.

Palomares, Spain[2, 3]

On January 17, 1966, a U.S. B-52 aircraft carrying four nuclear weapons collided with a tanker aircraft during refueling and crashed near Palomares, Spain. Two of the weapons dispersed plutonium over an area of 650 acres as the high explosive detonated on impact. As remedial action, all crops were stripped and destroyed where readings were above 5 μg plutonium/m^2; all areas where readings were between 5 and 500 $\mu g/m^2$ were plowed to a depth of at least 10 inches; areas with readings over 500 $\mu g/m^2$ were stripped of topsoil. Contaminated material was placed in 4,600 55-gal steel drums and shipped to the United States for burial. Topsoil was removed from 5-1/2 acres and 600 acres were plowed. Eight hundred U.S. military personnel performed decontamination over a period of 81 days. The total cost, not including the lost aircraft and weapons, was about $100 million. Although crop damage payments exceeded $650,000, within a few months following cleanup, produce from the area was again accepted in markets.

Thule, Greenland[3, 4]

On January 21, 1968, a U.S. B-52 aircraft carrying four nuclear weapons developed an on-board fire and crashed on sea ice in Bylot Bay, Greenland. The high explosive component of the four nuclear weapons detonated, and plutonium was further spread by the burning of 225,000 pounds of jet fuel. An area of approximately 400 feet by 2,200 feet was contaminated with levels as high as 380 mg/m^2 of plutonium. Approximately 550 personnel were involved in search and cleanup over a two-month period. About 237,000 cubic feet of contaminated debris were removed and shipped to the United States for burial. Ecological studies completed after the ice melt found no significant contamination either on the land mass or in the marine environment.

Other Nuclear Weapons Accidents[1]

Some 95 nuclear weapons accidents, most with no or only minor loss of containment, have been documented. Most are listed as cleanup by military personnel.

Enewetak Atoll[5, 6]

From 1948 to 1958, the Unites States conducted a total of 43 nuclear weapons development tests on or near the Enewetak Atoll. The radiological clean-up operation ran from 1976 through 1979, cost about $87 million and required an on-atoll task force numbering almost 1000 people.

The clean-up criteria were based on dose limits to individuals of no greater than 50% of the Federal Radiation Council annual rate limit and 80 percent of the 30-year generic limit. This led to guidance that soil should be removed if the plutonium concentration exceeded 400 ρCi/g of soil, and should be left in place if the concentration was less than 40 ρCi/g. For concentrations in the range of 40-400 ρCi/g, decisions were to made on a case-by-case basis, considering the potential island use (<40 ρCi/g residential, <80 ρCi/g agricultural use, <160 ρCi/g food gathering). Cleanup focused on plutonium, since cesium-137 and strontium-90 were considered too widespread and incorporated into vegetation to be effectively removed without severely damaging the ecological system. Approximately 104,000 cubic yards of soil and 6,000 cubic yards of contaminated scrap were removed for encapsulation. The total curies contained were estimated at 14.7 Ci.

There were no significant beta/gamma or plutonium uptakes among clean-up workers. All external exposures were negligible (less than 1 percent of limits). Six U.S. service men died in the clean-up effort.

Resettlement of native Marshallese was completed in October 1980. Subsistence crops were established by that time.

Morning Light[7]

In January 1978, a Russian nuclear powered satellite, Cosmos 954, fell to Earth. The reactor was a liquid metal cooled, enriched uranium, beryllium reflected fast reactor. Cosmos fragments were scattered across a 30-mile-wide, 500 mile-long swath of the Northwest Territory of Canada. This was/is a desolate area, populated only by a few Inuit hunters and an occasional hunting community. Radioactive fragments ranged from a few milliRoentgen to 100 Roentgen per hour. Several hundred U.S. and Canadian personnel were involved in locating and removing radioactive material. Recovery operations were completed on April 8, 1979, though some small, low-level particles were still being found in the following summer. The initial response and mapping of the contamination spread cost about $4.4 million, the final recovery cost added $3 million.

Rocky Flats[3, 8]

The U.S. Department of Energy operated a weapons component fabrication plant at Rocky Flats, Colorado, from 1952 to 1989, when the plant ceased operations and went into cleanup. Due to a fire, small routine releases, and a spill from stored cutting oil, approximately 3.5 curies of plutonium were released to the environment offsite. This contamination measured 50 mCi/km^2 near the site to levels slightly above background 10 miles out. Although an area of approximately 500 acres was involved, the decision was to fence the area and control access rather than attempt cleanup. Arguments continue today as to the appropriate clean-up level and costs.

Other Nuclear Weapon Production Sites [9, 10]

The Department of Energy has further experience at cleanup and remediation of plutonium spills at other nuclear weapons-related facilities. Fifteen curies of plutonium-238 were removed from a drainage canal at the Mound Plant in Miamisburg, Ohio, in 1969 at a cost of $48 million. Several sites have been cleaned up at the Los Alamos National Laboratory and one at Livermore, California. Cleanup levels in these cases were determined by land use and projected population dose.

Summary of Experience, Clean-up Standards, Costs

Fortunately, the incidents cited above were not in densely populated areas. Thus, rather draconian clean-up measures (removal of contaminated structures and soil) could be completed. A terrorist event may be expected to occur in more populated areas where far more expensive actions may be required.

Clean-up standards may be expected to start with the EPA recommendation based on 1 cancer/million/year residual risk level[11] or NRC published criteria[12]. DOE has developed a computer risk assessment model (RESRAD) to assess environmental and human health risks at sites contaminated with radioactive materials. RESRAD is a pathway analysis computer code that calculates radiation doses and cancer risks to critical population groups and derives clean-up criteria for radioactively contaminated soils. It is available from Argonne National Laboratory.

However, each of the incidents described above resulted in considerable debate as to the appropriate levels and course of action Funding and political considerations were often the decision drivers. Each case will be unique and will require independent evaluation, but the spread of even a few curies may be expected to cost in the order of $100 million to clean-up.

Recommendations/Expectations Following a Dirty Bomb Event

[Perhaps a scenario of a RDD event with consequence assessment]
(Interface with Brooke s paper)

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