PLUTONIUM CONTAMINATION OF LARGE LAND AREAS

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Abstract—The contamination of large land areas with significant quantities of plutonium has been essentially a situation unique to the non-nuclear detonation of nuclear weapons. However, with the increased use of Pu-239 for non-weapons applications and the availability of Pu-238 in quantity, health physicists need information on the magnitude of the contamination associated with plutonium accidents.

The results of the most extensive field experiments to date, Operation "Roller Coaster" sponsored by the United States and the United Kingdom, provide an insight into the radiological problems of such accidents. As is the case in any true accident involving radioactive material, it is necessary to function and evaluate under conditions entirely different from routine plutonium operations. Special equipment was field tested to enhance plutonium detection by low energy electromagnetic radiations in addition to more conventional alpha monitoring. These techniques may be applied to improve personnel safety and to speed up the collection of radiological measurements where Pu-238, Pu-239, Am-241 and other transuranic elements are involved.

If this were an audience of the general public, a more intriguing title would be "The Two Faces of Plutonium". However, in speaking to this very distinguished group of health physicists, much of the background and historical data on plutonium can be omitted. It is sufficient to comment that the discovery, introduction and use of plutonium have been accompanied by radiological protection measures of unprecedented magnitude. Continuous air monitoring, isolation techniques, protective equipment, special instrumentation and complete bioassay programs have become the acceptable practice wherever plutonium is handled.

Opposed to this is the plutonium contamination of large land areas when essentially all of these control mechanisms are difficult if not impossible to institute. This is a situation unique to the non-nuclear detonation of a nuclear weapon wherein the *chemical* explosive is detonated at some point in handling, storage or transportation. It was thrust into the limelight of international news last January over the southeast coast of Spain during an inflight refueling operation of two aircraft of the U.S. Air Force.

What information is available to the health physicist who may find himself at the scene of a plutonium accident? Fortunately, extensive field experiments, notably Operation "Roller Coaster" conducted jointly by the U.S. and the United Kingdom, provide an insight into some of the problems. In truth, accidents involving plutonium may be categorized as any other radiation accident where the health physicist should:

(a) Have a clear understanding of the problems to be solved and their order of priority.
(b) Reorient himself as to acceptable levels of exposure and contamination.
(c) Be current on measurement techniques for a variety of circumstances.

Taking these categories in order one must first consider the saving of life and property. Or a fire may be involved where precedence is given to extinguishing it. Highly sensitized chemicals which will detonate on contact may be found in the debris. There is the possibility that a small fission contribution may have occurred during the explosion. In this case energetic gamma radiation of 1000 r/hr or more may be encountered. Radiological controls will be governed by this radiation regardless of the presence or absence of plutonium contamination. Other debris must be approached with caution because it will exist in a twisted and jagged form such that contaminated wounds may occur frequently. Obviously daytime operations are preferable, if not mandatory. Control of access and egress of personnel and equipment must be established regardless of the radiological situation. Non-essential personnel are removed and upwind control points established.

when the site is re-opened to unrestricted traffic.

Just as in the case of the radiation accident involving fission products or energetic gamma sources it is necessary to shift gears mentally in evaluating contamination levels of significance. For example, we concern ourselves daily with the measurement of exposure rates of a few mr/hr or less, while at the accident scene we deal in many multiples of r/hr. To bring the situation under control one has to devote attention to dose rates of this magnitude. Similarly

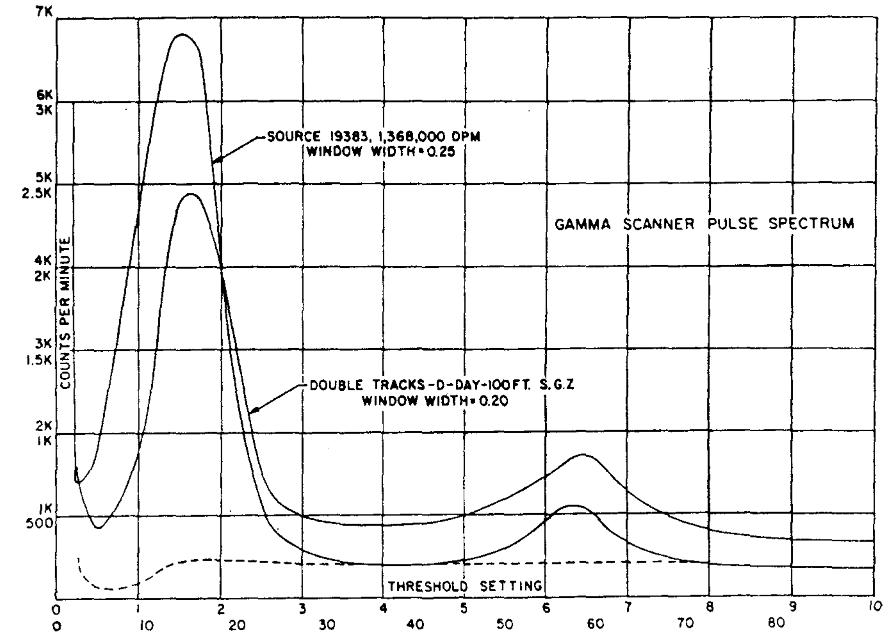

FIG. 1. Electromagnetic radiation spectrum of standard plutonium source (19383) and postdetonation debris (double tracks).

Having progressed to this point, one can begin to think about plutonium contamination, monitoring assignments and other radiological protection measures associated with alpha contamination. As a general rule, it is preferable to isolate the area of immediate concern by moving "in" toward the center and to follow this by moving "out" to the more distant points. These actions will define the magnitude of the area in preparation for the second, or long-term effort, which can be approached in a more leisurely, planned manner and which concludes

where plutonium is involved, one cannot be diverted from the immediate mission by a strict accounting of all places where laboratory tolerances of 100 cpm or 500 cpm or 1000 cpm may occur. To be quite blunt, until a portable alpha counter registers a completely off-scale reading, one has not located the area requiring priority attention.

While we are all prone to relate plutonium contamination monitoring to alpha measurements, it is not a pleasant thought to contemplate this "hands-and-knees" effort over tens

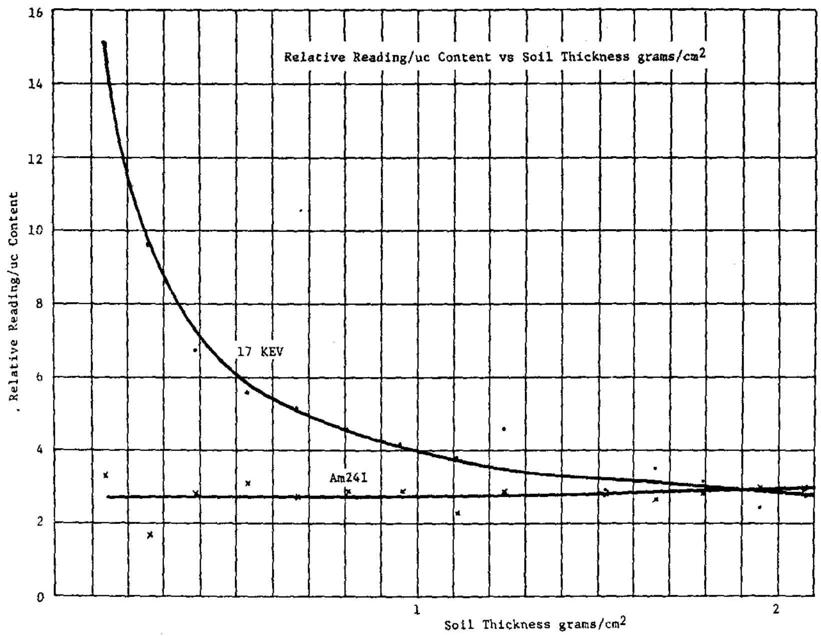

FIG. 2. Shielding effect of soil on 17 and 60 keV electromagnetic radiations.

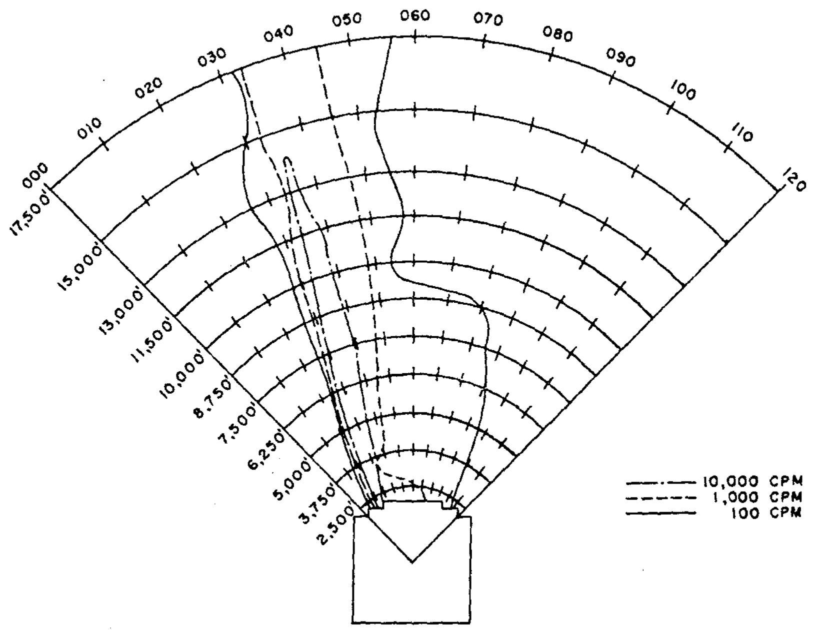

FIG. 3. Downwind alpha contamination plot following field experiment. Distances in feet are measured from detonation point.

of acres, square kilometers or square miles. As a matter of fact, it can exhaust you just thinking about it! So we look for a solution of convenience and try to do what we can with the electromagnetic radiations associated with plutonium. Figure 1 not only shows the expected 17 keV peak but also a second peak representing the Am-241 which occurs in varying minor percentages in all plutonium. Note that the Am: Pu ratio increases from a clean source to deposited fallout indicating the ease with which 17 keV can be effected by environmental conditions. Indeed, soil homogenously mixed with weapons grade plutonium contaminant will mask 17keV at a thickness of about 2g/cm² (Fig. 2). It is well to remember this potential for gamma detection in dealing with Pu-238 which exceeds that of Pu-239 by several orders of magnitude because of its higher specific activity, abundance and energy.

To bring this discussion to practical terms, a fairly typical fallout pattern is shown in Fig. 3. It developed, as would be expected after an explosion, in the downwind pattern of the prevailing meteorology. At 2500 feet the maximum contamination level was between 10,000 and 100,000 cpm/60 cm² probe area. This means that the area of immediate concern is relatively confined. As one approaches the centre, however, contamination levels increase rapidly and irregularly being the result of a "debris throwout" phenomenon rather than true fallout. Removal of debris, especially metallic debris, is an effective decontamination measure in the area.

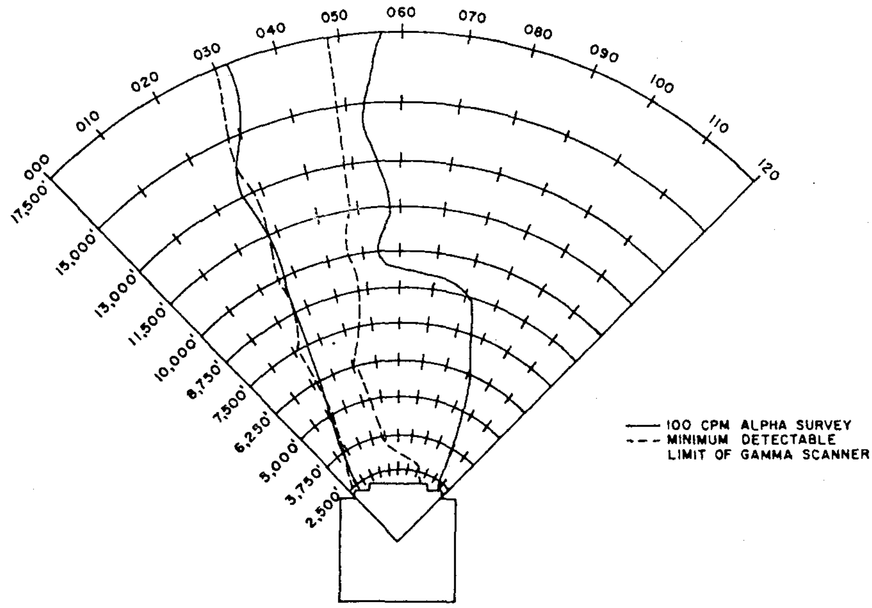

FIG. 4. Portable alpha counter vs mobile low energy gamma scanner (Fig. 5) contamination plots (compare with Fig. 3).

The comparative sensitivity with low energy gamma detection is given in Fig. 4. The alpha and gamma contours are most consistent at greater than 1000 cpm alpha. These data were taken with a specially designed vehicle (Fig. 5).

The shielded detector projects in front and the electronics (single channel analyzer) and readout are mounted inside the cab. The bicycle wheel in the rear is synchronized with the recorder chart drive for positional reference. The large appurtenance on top is an air conditioner added for personal and equipment requirements in hot climates. At the sacrifice of one or two

FIG. 5. Mobile low energy gamma scanner.

orders of magnitude in sensitivity, a gamma detection device can be made completely portable at under 10 lb total weight. Developments are presently under way to retain sensitivity in a 20 lb device with microcircuitry though the complete product is some 2–3 years away.

A few personal conclusions on associated problems are in order. First, plutonium depositions on land are quite resistant to resuspension. After the passage of the explosion-formed cloud, the hazard decreases by probably a minimum factor of 100. Further reduction through simple stabilization measures (water spray, etc.) is effective.

Secondly, percolation into soil is extremely limited if a factor at all. The top inch contains nearly 100% of the contaminant even after long weathering. This means that soil decontamination is best accomplished by the removal of a thin layer—thinner than is feasible with large earth moving equipment, unfortunately.

Air concentrations related to operational activities of personnel are difficult to obtain. These activities are not repetitive either in time, location or function. One normally provides respiratory protection in the form of the full face mask without benefit of air concentration information.

The August 1966 Newsletter of the Health Physics Society carried a summary of the report of the Society's Civil Defense Committee. One of the statements in this report encouraged members to become acquainted with the "procedural differences between these [accidents] and the usual peace-time operations". The weapon accident or other plutonium-scattering events, as infrequent as they may be, do require procedural differences. It should be emphasized that they are completely manageable with safety and thoroughness when competent personnel have planned for them.