ELECTROSTATIC CURTAIN EXPERIMENTS

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ABSTRACT

This paper presents the results of proof-of-principle experiments using electrostatic curtains as a transuranic contamination control technique. The transuranic contaminants to be controlled include small (micron to submicron) particles of plutonium and americium compounds associated with defense related waste. Soil containing Pu-239 and Am-241 from a mixture of Rocky Flat Plant contaminated soil and Idaho National Engineering Laboratory uncontaminated soil was used. The experiment was conducted inside a glove box in which electrically charged metal plates and fabric coupons were placed. The data for these experiments consisted of the mass of dust collected on the various sample coupons, plates, and filters; radiochemical analysis of selected dust samples; and photographs from the scanning electron microscope. Because of the positive charge, plutonium and americium particles were strongly attracted to plates with a negative charge. Some plutonium attached to negatively charged dust particles was also found on positive plates. The trend was for radioactivity per gram to increase as the particle size decreased. The conclusion is the electrostatic curtain has potential as a contamination control technique.

INTRODUCTION

This paper presents the results of proof-of-principle experiments using electrostatic curtains (ESCs) as a transuranic contamination control technique. The transuranic contaminants to be controlled included small (micron to submicron) particles of plutonium and americium compounds associated with defense-related waste. Contamination control during handling of transuranic materials is important because of the extreme radiological and toxic hazards of small amounts of these materials. An example of the potential application of ESCs is the retrieval of stored or previously disposed transuranic waste under earth cover. During retrieval operations, plutonium and americium compounds can become attached to dust aerosols that are highly mobile and require control.

The experiments used soil that contained Pu-239 and Am-241 from a mixture of Rocky Flat Plant (RFP) contaminated soil and Idaho National Engineering Laboratory (INEL) uncontaminated soil. The as-received RFP soil was sieved to determine soil particle size fractions and was analyzed to determine Pu-239 and Am-241 concentrations. Sufficient material from each type was blended to obtain a mixture that provided approximately 500 pCi/g of activity from the Pu-239 and Am-241. This soil blend was dried to less than 10% moisture content by weight to maximize aerosolization in the glove box.

OBJECTIVES

The primary objective of the ESC experiments was to determine if the ESCs could be used to control dust and radioactive contaminants in a simulated waste recovery operation. In addition there were secondary objectives to determine if:

a. Pu-239 and Am-241 aerosol particles would be attracted to or repelled from an electrically charged plate when the aerosol passed through the electrostatic field between the charged plate and ground;
b. the radioactivity per gram of the aerosol particulates varied with particle size;
c. the amount of dust attracted to a single metal plate immersed in an aerosol was more for plates that were grounded than for plates that were ungrounded, and how it varied if the plates were insulated;
d. the amount of dust collected out of an aerosol passing through an electrostatic field between two charged plates was affected by (a) the polarity of the voltage on the plates, (b) grounding arrangement of the plates, and (c) insulation of the plates; and
e. the amount of Pu-239, Am-241, and dust collected on fabrics with a conductive coating and that are grounded was greater or less than fabric without the coating.

BACKGROUND

Most airborne particles are electrically charged. The level of charge is dependent upon the process by which the particle is generated. Particles may be generated by radioactivity, aerosolized by dispersion techniques, or formed by vapor condensation. A radioactive waste recovery process will generate particles by dispersion from the digging process, as well as radioactivity. All airborne particles, whether charged or neutral at the time of generation, will ultimately develop a Boltzmann charge distribution by colliding with the ions in the surrounding air. The Boltzmann charge may be regarded as the natural minimum charge on the airborne particles. The root-mean-square (rms) charge on a 1 μm diameter aerosol in Boltzmann equilibrium is approximately 3 elementary units, with the rms charge increasing as the square root of the particle size (1). This means the coulombic electrostatic attraction becomes stronger as particle size becomes smaller.

Previous investigations found that alpha-emitting materials such as Pu-239 and Am-241 develop a positive charge due to loss of electrons with each alpha emission (2). Results of additional work on radioactive aerosols and electric fields indicated the possibility of collecting (controlling) alpha- and beta-emitting particles with an ESC. Experiments indicated that there was a difference in the movement of PU-239 to insulated electrodes from that of conducting electrodes*. However, results of experiments using an electrostatic device were inconclusive**. Further study was needed to understand the complex interaction of aerosols and electrostatic fields before an effective control technology could be developed. For example, electrostatic fields may occur naturally on plastic materials due to friction between the material or naturally due to ionized air currents. Those fields may actually aid contamination migration to or from the plastic materials.

DESCRIPTION OF EXPERIMENT

The experiment was conducted inside a glove box using test equipment that consisted of a dust generator, an Andersen cascade impactor***, cyclone samplers, sample holders, a power supply, and associated wiring. The glove box was 60.96 cm wide, 76.2 cm high, and 152.4 cm long, with three glove ports. Inlet and exhaust air were filtered, minimizing the effect on (a) experimental error due to particulates in the inlet air and (b) impact on room air caused by the exhaust air. Linear air flow through the glove box could be controlled from 0 to approximately 70 linear ft/min through the use of a modified high volume air sampler. Dust was generated by blowing pressurized air through a Dacron tube that had numerous holes in it. This tube was placed in the bottom of a V-shaped dust generator, and the air blew through the soil suspending the fines into the air.

The experimental investigations were quantified by measuring the amount of aerosolized contaminated dust collected on grounded and ungrounded coupons and on insulated and uninsulated plates that were charged either positively or negatively. Additionally, separation of plutonium and americium particles from dust particles by electrostatic means was examined. Size distribution of the aerosol was determined using an Andersen cascade impactor. The respirable fraction of particles in the aerosol was determined using cyclone samplers. Radiochemistry analysis for selected samples was performed to determine Pu-239 and Am-241 content. A scanning electron microscope (SEM) was used to identify particles containing plutonium on coupon and filter samples, as well as obtaining photographs of particles collected.

The coupons consisted of 2 $in.^2$ material samples from anti-C clothing, commonly used plastics, and a hazardous waste bubble suit. A conductive anti-static coating was sprayed on selected fabric materials to determine the effect of grounded and ungrounded materials. The fabric and plastic coupons were attached to a copper wire frame held in place by a Plexiglas base; up to six wire frames with coupons could be held by a base.

Aluminum plates (0.05 x 4.44 x 5.71 cm) that could be weighed on a $\pm$0.0001 gram balance were used in the experiments. Both painted and unpainted plates were used to determine what effect insulation (paint) had on collecting dust, Pu-239, and Am-241. The plates were placed in parallel slots cut in Plexiglas fixtures. Each fixture held up to five plates that were spaced in the slots 1 cm apart. The arrangement for the electrically charged plates was five plates with the center plate and two outside plates grounded. The second and fourth plates had 300 V applied, which would provide an electric field between the grounded plates and each charged plate of 30,000 V/m. One set of such plates was charged by connecting to a positive 300 V source with respect to ground, and another set was charged with a negative 300 V power supply. Another group of plates was assembled with all the plates grounded, and still another group in which they were left ungrounded. Similar sets of plates coated with a latex paint (insulated) were assembled and connected electrically in the same way as the uncoated plates. The type and number of coupons and plates used in the experiments are given in Table I.

Two power supplies were placed near the glove box that provided the positive and negative 300 V as well as a reference point for the system ground. The power supplies and ground wires were connected to the various coupons by means of cables run through a feedthrough in the glove box.

The experiment was initiated by turning on the modified hi-Vol sampler to establish a negative pressure in the glove box. The cyclone samplers were then turned on, followed by the air supply to the aerosol generator. The experiment was conducted for 15 min, which was sufficient time to get a visible coating of dust from the dust cloud on the coupons. The Andersen cascade impactor was turned on for approximately 5 min during the experiments to collect samples for determining particle size distribution of the aerosol. When the dust settled, all of the coupon and filter samples were weighed and the preexperiment weights subtracted to get the net dust collected on each. Samples were

* Letter from J. L. Alvarez to C. K. Mullen, "Charging and Control of Radioactive Particles," April 19, 1988.

** Unpublished research results by L. D. Watson on electrostatics and radioactive particles, September 2, 1988.

*** References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof.

TABLE I

Type and Number of Coupons for Each Treatment

Type of Coupon	Ungrounded	Grounded	Grounded -300 V	Grounded +300 V	-300 V	+300 V
Aluminum	4	4	3	3	2	2
Painted aluminum	4	4	3	3	2	2
Polyethylene	4	4	--	--	--	--
Bubble suit	4	--	--	--	--	--
Bootie	4	4	--	--	--	--
Coverall	4	4	--	--	--	--
Shoe cover	4	4	--	--	--	--
Glove	4	4	--	--	--	--
Totals	32	28	6	6	4	4

selected for chemical analysis, and additional samples were selected for viewing with the SEM.

RESULTS OF THE EXPERIMENTS

The results of the experiments indicate plutonium and americium are attracted to both positive and negative plates as shown in Table II. However, more of the plutonium (171 pCi/g) and americium (38 pCi/g) is attracted to the negative plates than positive plates (53 pCi/g and 14 pCi/g). This was expected because plutonium and americium develop a positive charge when the alpha particle leaves the nucleus, stripping electrons and leaving the atom with a net positive charge. Unpainted negative plates attracted more plutonium than painted negative plates. A small amount of plutonium was found on the positive plates, which indicates some plutonium attached to negatively charged dust particles that in turn attached to the positively charged plates.

TABLE II

Amount of Dust, Plutonium, and Americium Collected on Selected Metal Plates

Plate	Mass (mg)	Pu (pCi/g)	Am (pCi/g)
Grounded	3.0	74	14
Ungrounded	12.3	85	34
-300 V	5.0	171	38
+300 V	8.5	53	14
-300 V insulated	5.9	154	64
+300 V insulated	9.5	33	13

Fabric materials with a coarse weave or rough surface collected more dust than smooth materials, regardless of grounding or conductivity. When a smooth conductive coating was applied to provide a surface for grounding, less dust was collected. A grounded surface did not consistently collect more or less dust than ungrounded surfaces because of the roughness factor and the various amounts of charge that could be collected on ungrounded surfaces. The dust collected on the fabric and plastic coupons is given in Table III.

The cascade impactor data are presented in Table IV. These data show 44.73% of aerosol particle size was greater than 10.2 μm and 17.14% was less than 1.2 μm. The radiochemical analysis (also presented in Table IV) shows the pCi/g of Pu-239 increased as the particle size decreased, ranging from 47 to 137 pCi/g. The amount of Pu-238/Am-241 appeared to be about 9 pCi/g for particle sizes greater than 4.2 μm and jumped to around 20 pCi/g for particles less than 4.2 μm. The contents of cyclone sampler number five was examined with the result showing the respirable fraction of the dust had a radiochemical analysis of 142 pCi/g of Pu-239 and 97 pCi/g of Pu-238/Am-241, as shown in Table V. The same table shows the radiochemical analysis of the nonrespirable dust (particles $>10 \mu$m) as 90 pCi/g for Pu-239 and 51 pCi/g for Pu-238/Am-241. Particle size distribution appeared to be an important factor affecting collection efficiency.

A measurable amount of dust was collected on all plates, regardless of treatment. However, the +300 V plates collected the most dust, with an average of 9.9 mg for the metal plates and 9.95 mg for the insulated plates, as shown in Table VI. The reason for this is the aerosol particles generated by the dispersion technique acquired a net negative charge and, thus, were attracted to the positively charged plate. In all six cases the insulated plates collected more dust than the uninsulated plates by an average of 7.03 to 5.12 mg. The metal grounded plates collected the least amount of dust at an average of 1.85 mg. One probable

TABLE III

Average Milligrams of Dust Collected on 2 in.^{2} of Fabric and Plasic Material

Material	Ungrounded	Grounded	Number of Samples
Polyethylene	4.58	5.95	8
Bootie	8.45	4.50	8
Coverall	4.45	4.88	8
Shoe cover	16.50	4.03	8
Glove	4.43	4.90	8
Bubble suit	7.65	--	4
Mean	7.67	4.85	
Standard deviation	6.16	1.80	
N	24	20	44

TABLE IV

Amount of Dust, Plutonium, and Americium Collected on Cascade Impactor Filters

Stage	Particle Size (microns)	Mass (mg)	Pu (pCi/g)	Am (pCi/g)	Percent of Total Mass
1	> 10.2	954.1	47.0	8.9	44.73
2	4.2 to 10.2	561.5	50.0	9.4	26.33
3	2.1 to 4.21	58.4	94.0	19.3	7.43
4	1.2 to 2.1	93.4	113.0	20.0	4.38
5	< 1.2	365.5	137.0	20.0	17.14

TABLE V

Amount of Dust, Plutonium, and Americium Collected on Cyclone Sampler Number Five

Cyclone Sampler	Particle Size (microns)	Mass (mg)	Pu (pCi/g)	Am (pCi/g)
Filter	< 10	3.3	142	97
Cap	> 10	0.8	90	51

reason for this is that the surface charge on a particle was lost to the aluminum plate and the particle may have then fallen off or become reentrained in the air flow. In the case of the insulated (painted) plate, the charge was not drained off and image charge or polarized charge forces held the particle on the surface until either the charge was neutralized or some other stronger force removed the particle.

SEM ANALYSIS

The SEM analysis not only provided pictures of the dust particles but also identified Pu-239 particles by using the compositional and dot mapping modes of SEM operation. As an example, a particle about 30 μm in size from the air outlet filter was identified as containing Pu-239, shown in Fig. 1. The significance of this photograph is that plutonium particles can be free and not attached to dust.

CONCLUSIONS

The conclusion from these proof-of-principle experiments is the ESC has potential as a contamination control technique. Because of the positive charge, plutonium and americium particles were strongly attracted to plates with a negative charge. The pCi/g of Pu-239 increased as particle size decreased. The smaller the particle size, the more efficient the ESC became for collecting radioactive particles. The aerosol particles generated by the dispersion technique in the glove box acquired a net negative charge resulting in positive plates collecting the most dust in every experiment. Some plutonium, apparently attached to other dust particles, was also found on the positive plates. On the average, insulated plates collected more respirable dust than uninsulated plates because the electrostatic charge was not drained off from the insulated surface. Thus, more dust attached to the surface due to electrostatic attraction. Fabric materials, in general, were not significantly different from one another, with the exception of coarsely woven materials and materials with rough surfaces. Grounded conducting surfaces seemed to collect the least amount of dust for respirable aerosols.

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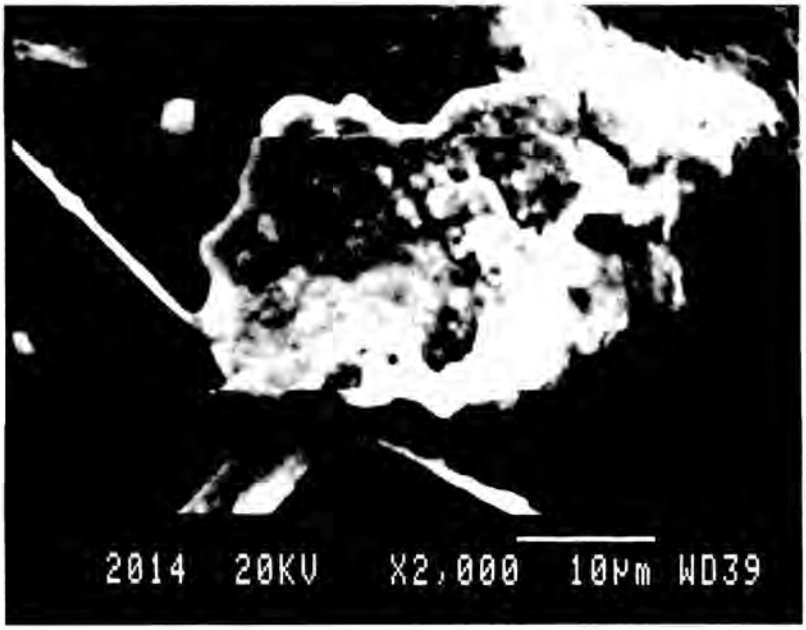

Fig. 1. A 30 μm -sized dust particle containing plutonium, SEM magnified ×2000.