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Effect of Electrostatic Charge on the Contamination of Plastic Food Containers by Airborne Bacterial Spores

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ABSTRACT

BARIBO, LESTER E. (Syracuse University Research Corp., Syracuse, N.Y.), JOHN S. AVENS, AND RICHARD D. O'NEILL. Effect of electrostatic charge on contamination of plastic food containers by airborne bacterial spores. Appl. Microbiol. **14**: 905–913. 1966.—Electrostatic charge of approximately −10 kv was produced by friction on polystyrene food container samples. This charge quickly decayed to a lower, more stable, level. Exposure of samples to positively charged red and negatively charged green fluorescent particles resulted in a particle-distribution pattern on the plastic surface. The dynamic attraction of fluorescent particles was illustrated by time-lapse photography. Similar distribution patterns of airborne bacterial spores were shown to develop. In controlled bacterial aerosol exposure tests, an increase in surface contamination of the plastic samples was found to be quantitatively related to an increase in negative electrostatic charge on the plastic. Static charge was found to accumulate on plastic food containers during their manufacture, and to remain indefinitely on many of the finished products. This charge was of the intensity and polarity to attract positively charged bacterial cells if such particles were present in the air.

The use of plastics as a food-contact surface has increased significantly during the past decade. Many types of single-service food containers and food packages now in commercial use are either impact-thermomolded from extruded sheets of high impact polystyrene, injection-molded from polystyrene or polyethylene, molded from foamed polystyrene, or constructed of plastic-laminate paperboard. Friction caused by high-speed manufacturing equipment induces an electrostatic charge on the highly resistive plastic. This static charge can increase the pickup of dust during subsequent stages of manufacture, storage, and use.

Woodland and Ziegler (13) have demonstrated the effect of static charge on the pickup of atmospheric dust by molded plastic tiles. In a subsequent study of electrostatic charges in plastics, Skinner et al. (12) found that high static charges were produced by the separation of plastic and metal surfaces joined by adhesives. It was indicated that a similar phenomenon occurred during plastic molding and stamping operations. These authors also found that static charge was induced on plastic materials by the friction encountered as they slid down metal chutes. McLaughlin (10) described techniques for the measurement of static charge on plastic webs moving through manufacturing equipment. Humphrey and Gaden (4) indicated that electrostatic charge on the fibers of filter mats used for aerosol filtration enhanced filtration of bacteria from air at low filtration rates. In a study of the antistatic properties of plastic bottles, Divis (3) described an evaluation technique in which a battery-operated electrometer was used for measuring the electrostatic charge on the bottle. In a subsequent study of the problem of dust collected on plastic bottles, Schanzle (11) suggested a new method for rating antistatic properties of plastic. In this method, an exposure chamber was used in which plastic bottle samples were exposed to controlled smoke-contaminated air, and the amount of smoke

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particle pickup by the plastic bottles was related to the level of static charge on the plastic.

The manufacture of plastic products as food containers will increase in the future. This emphasizes the importance of knowing the role of electrostatic charge in the bacterial contamination of plastic food-contact surfaces. The present study was initiated to determine the relationship between electrostatic charge on plastic and the contamination of the plastic by airborne bacterial spores.

MATERIALS AND METHODS

Test organism. Spores of *Bacillus cereus* (ATCC 4342) were cultured according to a method used by Lundgren and Bott (9). The stock spore suspension in saline, containing about 2×10^{13} viable spores per milliliter, was frozen in small portions and stored at −20 C.

Static build-up and decay. Five areas distributed symmetrically on each of four transparent, impact-molded, polystyrene food container closures [4 inches (10.2 cm) in diameter, 0.01 inch (0.03 cm) thick] were marked with ink on the nontest side. Each sample was charged for 1 min by holding the plastic surface against a revolving drum covered with wool fabric. Static charge was measured over each area immediately after friction treatment and also at various intervals up to 30 min. Static charge was measured with a portable, battery-operated electrometer, model 600 A (Keithley Instruments, Inc., Cleveland, Ohio), equipped with a small highly directional, static detecting probe (model 4503) positioned 0.25 inch (0.6 cm) away from the plastic surface.

The electrometer measures the potential difference in volts between the plastic surface and ground. The potential difference is directly proportional to the charge on the plastic. The charge on the plastic may be negative or positive in relation to ground. The electrometer has a very high impedance, so that current flow does not produce a voltage drop. All static measurements were recorded by use of a Sargent Recorder, model SR, connected to the output connector of the electrometer. Static decay curves were plotted for each area of each sample. The temperature was maintained at 21 C and relative humidity at 40% throughout the test.

Effect of static on airborne particles. A chamber (2.5 by 1.5 by 1 ft) was constructed and equipped with a fan to disperse charged fluorescent particles introduced through a port in the top of the chamber. A 9-w ultraviolet lamp was set opposite a sample holder. These were positioned under a cylindrical glass inlet port, 2 ft away from a camera at the opposite end of the box. This apparatus was set up in a darkroom under controlled temperature and humidity. The polystyrene food container closures were friction-charged and exposed to the cloud of fluorescent particles within the chamber. Fluorescent powders used in this study were B-3530, cerise, and B-3539, lemon yellow (Lawter Chemicals, Inc., Chicago, Ill.). Single samples were positioned in the dark box opposite the ultraviolet-light source. Fluorescent particles were introduced through the inlet port so as to fall vertically between the ultraviolet-light source and the sample. In the ultraviolet light, the fluorescent particles emitted visible light, enabling their action in the electrostatic field of the plastic sample to be photographed. Time exposures of 1 min at a lens opening of f = 3.5 were taken with Ektachrome 35-mm film in a camera equipped with a Kodak Wratten filter, no. 2A.

Bacterial contamination patterns on plastic. The polystyrene samples were exposed to airborne bacterial spores in a simple aerosol chamber (29 by 25 by 20 inches). The chamber was equipped with a squeeze-bulb atomizer to disperse airborne spores, a fan to gently circulate air, and a membrane filter assembly connected to a vacuum source to evacuate the chamber of spores after sample exposure.

Polystyrene samples were either friction-charged for 1 min or destaticized. A spore suspension of 2×10^{11} spores per milliliter was dispersed into the chamber after the samples had been vertically positioned. After a 2-min exposure period, the chamber was evacuated of airborne spores, and the samples were removed. The sterile velveteen surface of a replica plating unit (8) was placed against the exposed test surface of a sample and then touched to the surface of solidified Trypticase Glucose Yeast Agar (BBL) in a petri plate. The spore-distribution patterns on the plastic samples were thus replicated onto solid culture medium and became visible upon incubation. Similar patterns were obtained by other methods. Use of fluorescent dyes resulted in patterns which could be related to the bacterial patterns. Lack of patterns with destaticized samples indicated at least reasonable reproduction of the patterns.

Aerosol chamber. A special chamber was developed for exposing a number of plastic samples to a homogeneous bacterial aerosol under controlled temperature and relative humidity. Kethley et al. (6, 7) described a chamber developed to study bacterial aerosols. This work was used as a guide in constructing the aerosol chamber.

The inside dimensions of the chamber are 22.5 inches cubed. It was constructed of 0.75-inch plywood, lined with white Formica, and sealed with caulk. The four sample tunnels (6 by 6 by 26 inches) attached to the right side of the chamber, and the prechamber (10.5 inches cubed), were constructed of the same materials. Chamber doors and tunnel hatches were pressure-sealed with rubber gaskets and high-vacuum grease. There are eight air-sampling ports in the main chamber consisting of glass tubes projecting into symmetrically distributed areas of the chamber. Each of four settling ports, one in each quadrant of the floor, consists of a circular hole, 3.25 inches in diameter, sealed by the bottom of a petri plate pressed against a rubber gasket surrounding the hole. Petri plates can be removed from the bottom of the chamber by rotating the clamps which hold them in place. The four settling ports are covered by two aluminum slides which can be inserted and removed from the front of the chamber. Aluminum sample racks are loaded outside the tunnels, inserted into tunnels, and slid into the chamber by aluminum

foil and tape which is neatly cut by the saw-toothed end of the sample rack as it is eased into the chamber. The sample racks are manipulated by rods which protrude from the tunnel hatches through tight-fitting rubber grommets. The main chamber is equipped with a dial thermometer and a hygrometer. Details of the chamber are shown in Fig. 1 and 2.

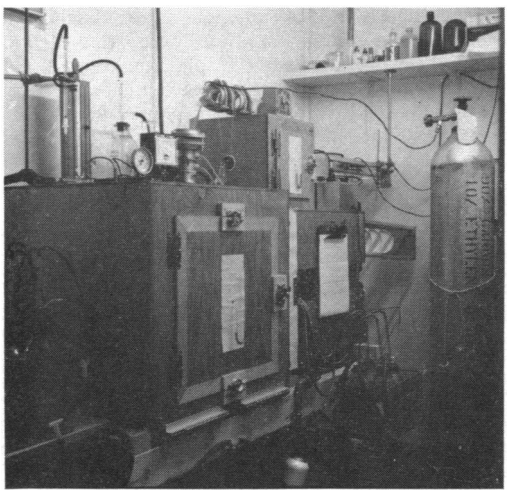

FIG. 1. *Aerosol chamber.*

The chamber was located in an insulated room in which the temperature and relative humidity (RH) were controlled within 1 C and 5% RH, respectively. This controlled air was drawn from the room by the inlet blower through the inlet filter, and was forced through a 2-inch diameter Pyrex glass pipe, a constricting 0.75-inch diameter orifice, and an air-diffuser, into the main chamber. The chamber air was continually exhausted through an exit pipe and bacterial filter by means of an exhaust blower, which then forced the filtered air outdoors. The air flow through the chamber was always less than 15 ft^3/min and was controlled by adjusting the blower speeds. Chamber pressure was adjusted to room pressure also by adjusting the blower speeds.

The standard bacterial aerosol was produced by atomizing a stock spore suspension (2×10^{11} spores per milliliter) into the prechamber. The dilute spore suspension was continually mixed in a 250-ml aspirator bottle by use of a magnetic stirrer. The spore suspension slowly emptied into a glass atomizer which was operated with 10.0 liters per min of filtered compressed air. The aerosol was forced through a one-way valve in the top of the prechamber into the main air stream, where it is mixed at the orifice and is uniformly dispersed throughout the chamber by the air-diffuser.

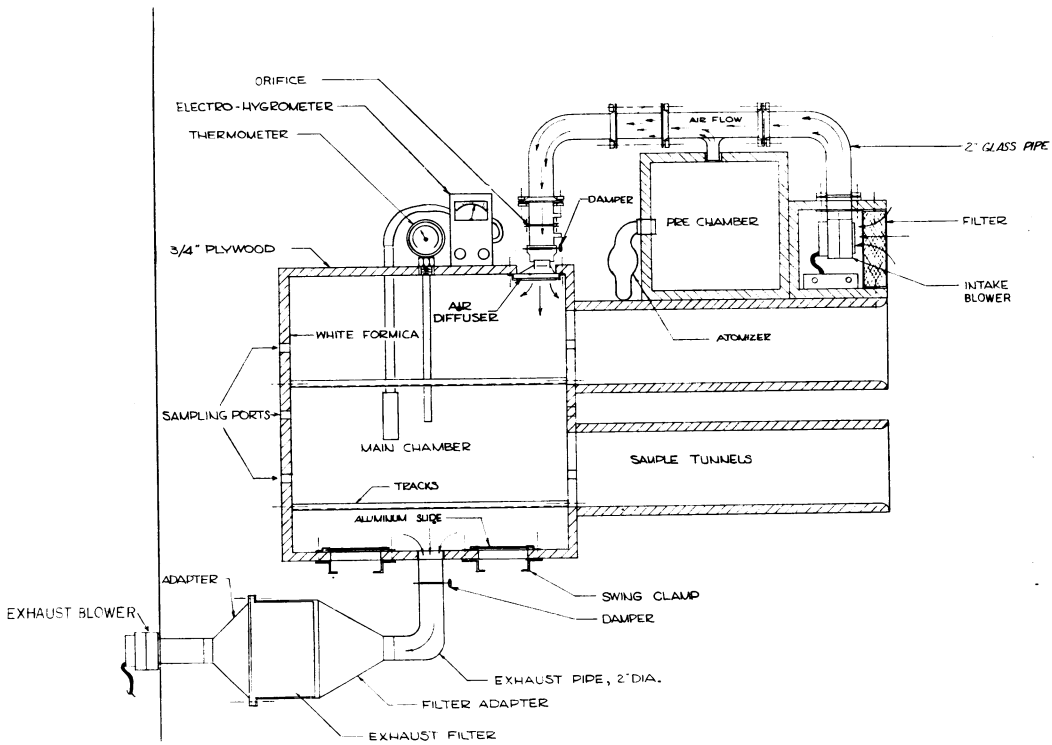

FIG. 2. *Aerosol chamber (schematic drawing).*

The aerosol chamber was tested for uniform dispersion of viable particles and for number of spores per particle by air-sampling methods similar to those used by Kethley et al. (6). Air samples were taken simultaneously during dynamic aerosol flow from eight areas of the chamber by means of critical-orifice liquid impingers (1). Samples were taken during two different 20-min intervals after at least 1 hr of dynamic operation of the chamber. Fallout samples were taken during four 20-min intervals. For each 20-min interval, two ports were sampled with Nutrient Gelatin (Difco) plates for the full 20 min. Simultaneously, the other two ports were sampled with Trypticase Glucose Yeast Agar (BBL) plates, three times during the 20-min interval for 1 min each time. Gelatin and agar plates were alternated between port pairs during each 20-min interval. Agar plates were incubated directly. The gelatin in each exposed plate was dissolved in 100 ml of sterile warm water and mixed in a sterile Waring Blendor for 10 sec. One drop of antifoam was added after mixing, and samples were plated. The average number of viable spores per viable particle in the aerosol was indicated by dividing the average viable spores settling per minute in the gelatin plates by the average viable particles settling per minute on the agar plates.

Quantitative relationship between static charge and plastic-surface contamination. Five impact-molded polystyrene food container closures, identical to those used in the static-decay study, were marked on the nontest side to indicate circular areas, 0.75 inch in diameter, distributed symmetrically on the surface. All samples were sterilized by ultraviolet radiation before exposure to the test organism. Plastic samples were either charged by friction, destaticized by scanning with a static neutralizer (Neutra-stat Head, model "B"), or not treated. Any charge built up was allowed to decay for 10 min to a steady level, and was then measured and recorded for each area of each sample. Measurements were made after ultraviolet irradiation was used to sterilize the plastic sample, thus eliminating any effect the ultraviolet radiation would have on the charge.

All samples, except an untreated blank, were clipped to the sample rack. The rack was eased slowly into the tunnel, after which the tunnel hatch was sealed. The aerosol chamber, which had achieved equilibrium by being in dynamic operation for 1 hr, was converted from dynamic to still conditions by simultaneously turning off both blowers, then shutting off the aerosol pressure, and finally closing the outlet and inlet dampers. The sample rack was then forced against the inner aluminum foil seal, cutting the foil and thus allowing the rack to be slowly inserted into the aerosol chamber. The sample rack remained in the chamber for 2 min, exposing the samples to an aerosol containing approximately 10 viable bacterial spores per liter, after which it was slowly pulled back into the tunnel. Outlet and inlet dampers were opened. The outlet blower was turned on to remove airborne spores from the chamber and create a vacuum so that the tunnel could be unsealed. Samples were removed from the rack, carefully turned to a horizontal position, and placed, test side up, in individual covered paper containers. After four such exposure tests, each test requiring one of the four chamber tunnels, the entire chamber system was sterilized with carboxide. The chamber temperature ranged between 20 and 23 C and relative humidity between 38 and 48% over all exposure tests. Samples were assayed for surface contamination by swabbing each marked area with three calcium alginate swabs. Each swab from each area was dissolved in separate 10.0-ml volumes of sterile Ringer's solution in screw-cap culture tubes. The contents of each tube were thoroughly mixed by vortex motion, poured into a petri plate, and swirled with Trypticase Glucose Yeast Agar. The total plate count for each swabbed area was related to the electrostatic charge measured over the area before sample exposure.

A study was made to determine what effect various exaggerated handling and environmental factors had on the static-contamination relationship. After exposure of four charged plastic samples to the bacterial aerosol, one sample was destaticized by scanning both sides with the static neutralizer, one was knocked 10 times in an attempt to dislodge spores from the surface, one was placed in the turbulent air of a fan, and the fourth received no treatment. These samples were then assayed for surface contamination as described above.

Static measurements taken on food containers during manufacture and storage. Static charge was measured on various materials at various stages of the manufacturing process according to techniques described by McLaughlin (10). The model 600 A portable electrometer was connected via a low-noise cable to a Keithley no. 2501 Static Detecting Heat (5). The static-detecting head was mounted in a specially constructed frame which supported it perpendicularly, $\frac{3}{8}$ inch (1 cm) away from a moving plastic web. This frame was held in both hands as it rode on the moving web on its two nylon roller bearings, each 6 inches (21 cm) to either side of the detecting head. The model 2503 Static Detector was used with the electrometer to measure static on small finished products. This study was carried out at two food container manufacturing plants. Residual static charge was also measured on packaged plastic food containers shipped periodically to the laboratory.

RESULTS

Static build-up and decay. The average static-charge intensity measured on each polystyrene sample immediately after friction treatment was approximately 10 kv. This charge rapidly decayed and at 1 min was at a lower, more stable, level, after which further decay became increasingly more gradual. After 10 min, very little change in static-charge intensity occurred over a subsequent 20-min period. Figure 3 shows plots of static-decay data for five areas on one polystyrene sample. Similar data were obtained from each of three identical samples. These data show that, in the subsequent bacterial aerosol exposure tests, there would be no significant change in

static-charge intensity on the samples between static measurement and exposure to the aerosol.

Effect of static on airborne particles. Areas of negative polarity selectively attracted red fluorescent particles, areas of positive polarity selectively attracted green fluorescent particles, and neutral areas were void of any particle attraction. This was shown by measuring the static charge over various areas of fluorescent color on the exposed plastic samples. The intensity of static charge was greater over areas of greater particle attraction, as shown by more intense color. Thus, static polarity and potential and distribution patterns can be indicated by fluorescent-particle attraction. Woodland and Ziegler (13) have previously shown similar patterns.

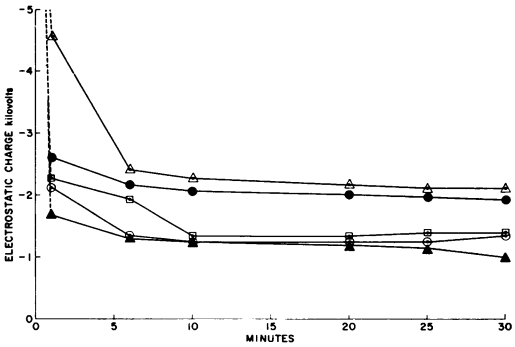

FIG. 3. *Static-charge decay from five areas* (○, △, □, ●, ▲) *of a friction-charged polystyrene food container closure.*

The fluorescent static patterns were more visible when illuminated with ultraviolet light. Enlargements from color transparencies enabled a detailed examination of the patterns. A typical pattern is shown in Fig. 5.

The dynamic action of charged, airborne, fluorescent particles in the electrostatic field of a charged polystyrene sample is illustrated in Fig. 4. The auroral band deviating from the vertical particle fall line was caused by many fluorescent particles moving over a similar path during the 1-min time exposure.

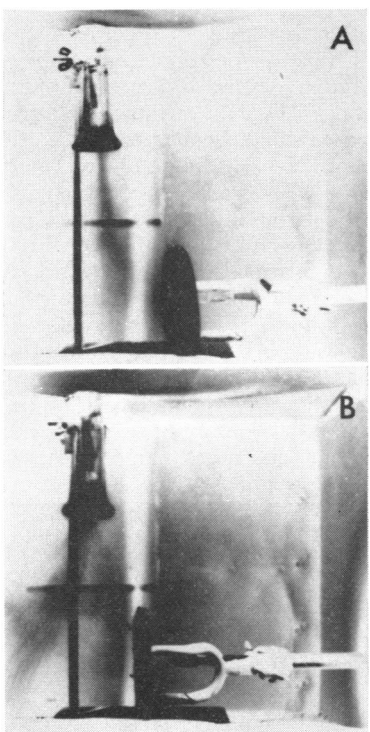

FIG. 4. *Dynamic action of charged fluorescent airborne particles in the electrostatic field of a charged polystyrene food container closure. (A) Positively charged red particles are attracted by the predominant negative charge on the polystyrene. (B) Negatively charged green fluorescent particles are largely repelled by the predominant negative charge on the polystyrene. Enlarged from 35-mm "Ektachrome" film.*

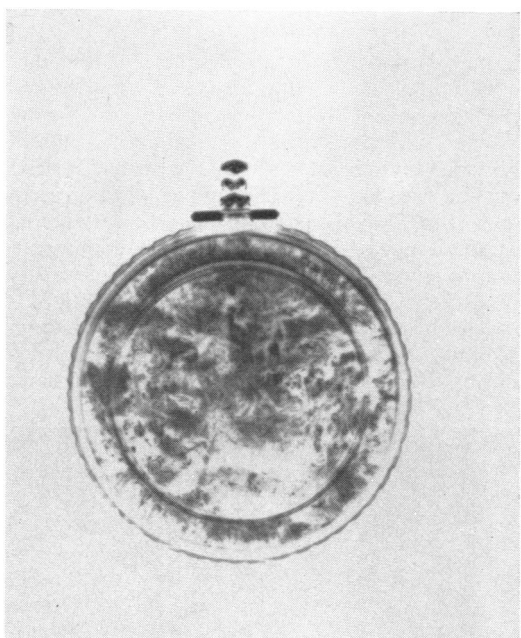

FIG. 5. *Fluorescent-particle distribution patterns on a friction-charged polystyrene food container closure, indicating polarity, potential, and distribution of static charge. The small, very dark branches are positively charged (green), the large dark areas are negatively charged (red), and the white areas are neutral (no particle attraction). Enlarged from 35-mm "Kodachrome X" film.*

Each polystyrene sample used exhibited a predominantly negative charge. The distance of the charged sample from the vertical particle fall line was a critical factor in causing deviation of the particles from this line. Very little deviation occurred at a distance greater than 4 inches (10.2 cm). Positively charged red fluorescent particles were attracted by the predominant negative charge on the samples (Fig. 4A). Negatively charged green fluorescent particles appeared to be repelled by this predominant negative sample charge (Fig. 4B). However, on examination of the samples, green particles were found to have been attracted in small amounts to the small positively charged areas and branches characteristic of a predominantly negative, charged plastic surface.

Bacterial-contamination patterns on plastic. Friction-charged polystyrene samples become contaminated by airborne spores to a much greater extent than destaticized samples. The few spores adhering to the destaticized samples were randomly distributed. Samples which possessed an electrostatic charge during the exposure test had definite areas on their surface to which airborne spores were preferentially attracted. This was evidenced by the distinct patches and branched channels on the "replica plates" that were completely void of bacterial growth and the bacterial colony distribution patterns (Fig. 6).

The bacterial colony distribution pattern obtained on "replica plates" (Fig. 6) had a striking resemblance to typical samples of fluorescent dyes (Fig. 5). This, plus the fact that destaticized samples showed relatively negligible contamination, qualitatively indicated that static electricity was directly related to surface contamination.

Aerosol chamber. Tables 1 and 2 show representative data from a series of tests performed during dynamic operations of the aerosol chamber. Statistical analysis of these data by use of Bartlett's chi-square test, Snedecor's F test, Student's t test, and the lsd test indicated a sufficient degree of homogeneity of the aerosol within the chamber, and the maintenance of a uniform aerosol over a period of time. This uniformity of dynamic operation was found to be maintained for more than 6 hr.

Table 3 compares average viable spores settling per minute with average viable particles settling per minute. The fallout counts from three consecutive dynamic runs of the aerosol chamber on 3 different days were averaged. An over-all average of 1.00 viable spore per viable particle was indicated by this method.

The data obtained indicated that the chamber is suitable for developing and maintaining a controlled experimental environment, homogeneously contaminated by single airborne bacterial spores.

Quantitative relationship between static charge and plastic-surface contamination. Figure 7 shows graphs of two typical sets of data which illustrate the relationship between electrostatic surface charge on a plastic food container sample and the contamination of the surface by airborne bacterial spores. The data of four polystyrene samples, exposed simultaneously to the aerosol, were plotted, and the best straight line was determined statistically. The correlation coefficients, indicating linear correlation between the two variables, were 0.8884 with a probability $\ll 0.001$ and 0.8690 with a probability $\ll 0.001$ for the two respective tests. Similar sets of data not shown gave the following correlation coefficients and probabilities: 0.6710, $P < 0.01$; 0.9424, $P < 0.001$; and 0.8376, $P \ll 0.001$.

Figure 8 shows a graph of data from the simultaneous aerosol exposure of two friction-charged samples, one uncharged sample, and one de-

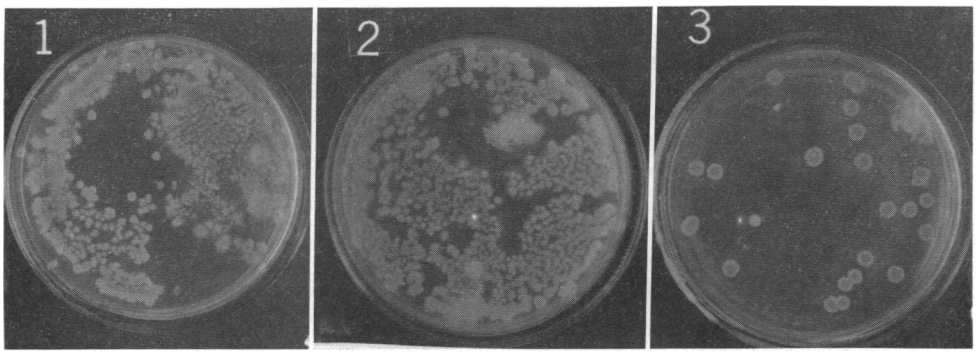

FIG. 6. *Colony-distribution patterns formed by the replica-plating technique, indicating the pattern of spore distribution on polystyrene samples exposed to a bacterial aerosol. Plates 1 and 2 represent polystyrene samples which were friction-charged before exposure; plate 3 represents a destaticized sample.*

TABLE 1. *Data of air samples taken from the aerosol chamber during dynamic operation at 21 C and 50% relative humidity, illustrating the distribution of viable airborne spores within the chamber*[a]

Sampling probe no.	Concn of spores per liter of air		Mean	SE
	60 to 80 min[b]	120 to 140 min[b]		
1	1,300	1,504	1,402	102
2	1,340	1,136	1,238	102
3	1,235	1,161	1,198	38
4	1,056	1,200	1,128	72
5	1,233	1,042	1,138	96
6	1,136	1,173	1,154	18
7	1,132	1,046	1,089	43
8	1,138	1,050	1,094	44
Mean	1,196	1,164	1,180	
SE	34	53		

[a] Variation between probes: $chi^2(1df) = 1.36$ ($P = 0.25$); variation over time: $chi^2(7df) = 5.01$ ($P = 0.67$); difference between time means: $F(1, 14df) = 0.259$, $1sd = 135.7$, $t(7df) = 0.715$ ($P = 0.5$); difference among port means: $F(7, 8df) = 1.82$, $1sd = 248.2$.

[b] After start of dynamic flow.

TABLE 2. *Data of fallout samples taken in the aerosol chamber during dynamic operation at 21 C and 50% relative humidity, illustrating the distribution of viable airborne spores within the chamber*[a]

Sampling interval (min[b])	Avg viable spores settling per min sampling port				Mean	SE
	A	B	C	D		
60–80	40	38	30	51	40	4.3
90–110	33	36	31	42	36	2.4
120–140	44	35	32	47	40	3.6
150–170	56	64	37	42	50	6.2
Mean	43	43	32	46	41	
SE	4.8	6.9	1.6	2.2		

[a] Variation over time: chi_c^2 (3df) = 6.36 ($P = 0.10$); variation between ports: chi_c^2 (3df) = 2.35 ($P = 0.53$); difference among port means: $F(3, 12df) = 1.74$, $1sd = 13.7$; difference among time means: $F(3, 12df) = 1.94$, $1sd = 13.4$.

[b] After start of dynamic aerosol flow.

staticized sample. An uncharged, unexposed sample was run concurrently as a blank. The best straight line for the points of the two charged samples gave a correlation coefficient of 0.8601 with a probability of < 0.01. The uncharged and destaticized samples measured less than ± 100 v over all areas, and had relatively little contamination. The uncharged unexposed blank sample measured less than ± 100 v over all areas, and had no contamination. Two identical experiments yielded similar data with correlation coefficients for the charged samples of 0.996, $P < 0.001$; and 0.7302, $P < 0.02$.

TABLE 3. *Data of fallout samples taken during three consecutive dynamic runs of the aerosol chamber, comparing average viable spores settling per minute with average viable particles settling per minute* [a]

Consecutive dynamic runs[b]	Sampling interval (min[c])	Gelatin plates		Agar plates	
		Sampling port	Avg viable spores settling per min	Sampling port	Avg viable particles settling per min
I	60–80	A	17	C	12
		B	29	D	10
	90–110	C	17	A	27
		D	30	B	47
	120–140	A	49	C	30
		B	53	D	36
	150–170	C	59	A	40
		D	59	B	64
II	60–80	A	31	C	28
		B	37	D	37
	90–110	C	23	A	27
		D	30	B	32
	120–140	A	48	C	36
		B	62	D	60
	150–170	C	29	A	53
		D	48	B	40
III	60–80	A	40	C	30
		B	38	D	51
	90–110	C	31	A	33
		D	42	B	36
	120–140	A	44	C	32
		B	35	D	47
	150–170	C	37	A	56
		D	42	B	65
Total			930		928

[a] 930/928 = 1.00 viable spore per viable particle.

[b] Consecutive dynamic runs were done at 50% relative humidity and the following temperatures: I, 23.5 C; II, 21 C; III, 21 C.

[c] After start of each dynamic aerosol flow.

Figure 9 shows the effects of destaticizing, knocking, and air movement on the static-contamination relationship of previously exposed polystyrene samples. The regular undisturbed contaminated samples gave correlation coefficients of 0.9068 ($P < 0.01$) and 0.9096 ($P < 0.01$) in two experiments. The destaticized contaminated samples gave slightly lower correlation coefficients of 0.8386 ($P < 0.02$) and 0.8037

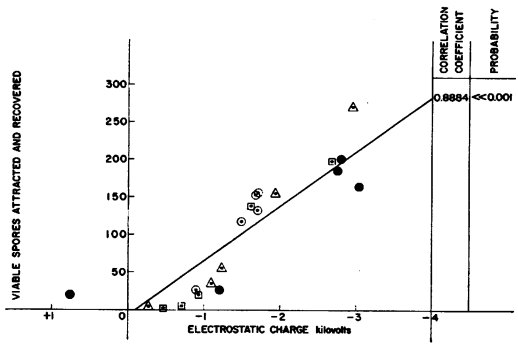

FIG. 7. *Relationship between electrostatic charge and surface contamination when four friction-charged polystyrene food container closures* (○, △, □, ●) *were simultaneously exposed to a bacterial aerosol.*

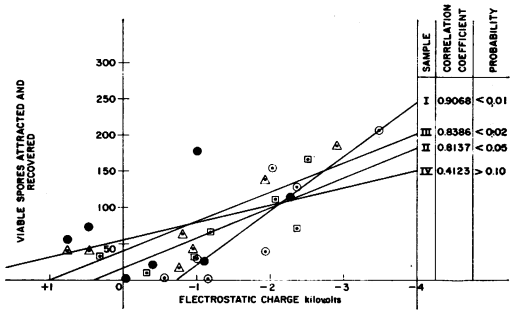

FIG. 9. *Effect of exaggerated environmental conditions on the static-contamination relationship of polystyrene samples, previously exposed to a bacterial aerosol. Sample I: regular, undisturbed* (○)*; sample II: knocked, 10 times* (□)*, sample III: destaticized, both sides* (△)*; sample IV: air movement, fan* (●).

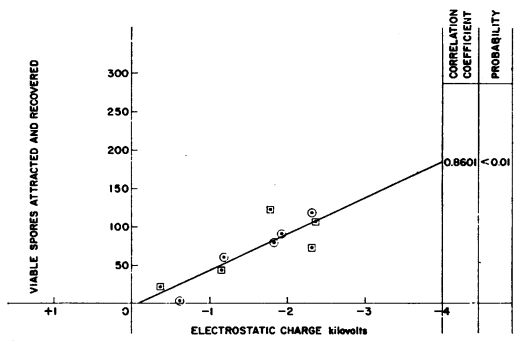

FIG. 8. *Relationship between electrostatic charge and surface contamination when two friction-charged polystyrene food container closures* (○, □) *were simultaneously exposed, with a destaticized and an untreated sample, to a bacterial aerosol.*

($P < 0.05$). The knocked contaminated samples gave varying correlation coefficients of 0.8137 ($P < 0.05$) and 0.1026 ($P \gg 0.10$) in the two experiments. The air movement effect varied radically, with a correlation coefficient of 0.4123 ($P > 0.10$) in one experiment and 0.9325 ($P < 0.01$) in the other.

Static measurements taken on food containers during manufacture and storage. The dominant polarity of charge on plastic material in the food container manufacturing process was negative. A positive charge of +1.4 kv was measured on plastic film near its point of contact with an impact molding machine. The highest negative charge measured was a −9 kv on a moving web of plastic laminating paperboard. It was found that the high negative charge built up on plastic laminated paperboard during contact with moving machine parts decayed readily to a low level of 0 to 150 v after friction was stopped, but the molded plastic materials retained a higher residual charge of −1 to −3 kv for a much longer period of time. Uncoated and wax-coated paperboard was found to accumulate a much lower static charge, −100 to −400 v, of which a negligible amount was retained on the finished product.

DISCUSSION

Laboratory data presented in this study showed that increasing negative electrostatic charge, as measured by the potential difference in volts, to a maximum of −3.48 kv on a plastic surface, causes proportionately increasing numbers of airborne spores to be attracted to the charged surface. It is assumed that, in the same aerosol, higher static charge would attract a larger number of airborne spores from a farther distance.

The charged plastic surface has both negatively and positively charged areas. The plastic-surface contamination results show that the viable bacterial spores were attracted to the negatively charged areas and, therefore, that they must have a relative positive charge. The attraction of bacteria will depend on the potential difference between the bacteria and the plastic. Electrophoretic-migration studies and isoelectric point of bacterial protein have shown gram-positive organisms to have a positive charge in relation to gram-negative organisms, indicating that there are different charges on different bacteria. With varying charge on the plastic and varying charge on bacteria, we might expect that those organisms with the greatest potential difference between their charge and the plastic would be attracted to a greater degree than those with a lower potential difference. If the organisms which have a large potential difference had public health significance, a small concentration contaminating the manufacturing area and packag-

ing area could seriously compromise the sanitary quality of the plastic.

Electrostatic charge as high as −9 kv was measured on moving plastic webbing at one stage of the plastic food container manufacturing process, and a considerable residual charge was found to remain indefinitely on some finished products. Plastic-container materials in the manufacturing process could be expected to be more susceptible to contamination by airborne microorganisms. The data show that such contamination would adhere to the plastic surface under many industrial conditions of air movement and product handling. Plastic food containers have a greater chance of becoming contaminated before they come in contact with food than do paper or wax-coated products. There is a need in the food container industry to develop methods to eliminate, or at least control, electrostatic charge on plastic. Further work on the effect of humidity on the static charge should be carried out. Control of humidity may be a practical means of controlling static charge in production.

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