Chapter 8

AIRBORNE MICROORGANISMS IN A DOMESTIC WASTE TRANSFER STATION

Irma Rosas
Carmen Calderón
Eva Salinas
John Lacey

CONTENTS

1-56670-206-2/96/$0.00+$.50

I. ABSTRACT

Culturable airborne bacteria and fungi were sampled in a domestic waste transfer station in Mexico City. Close to where the waste was handled, the geometric mean concentration of bacteria was >6700 cfu/m^3 of air, of Gram-negative bacteria >460/m^3, and of fungi >4900 cfu/m^3, of which 75% were *Penicillium* spp. Concentrations of microorganisms downwind of the waste site were greater than upwind. *Salmonella* was recovered on Trypticase Soy Agar from 14% of samples. The large concentrations of Gram-negative bacteria and fungi in the waste transfer station could lead to different types of pulmonary reactions, and thus constitute a respiratory hazard to workers, and possibly also to the neighboring population.

II. INTRODUCTION

Mexico City is one of the largest cities in the world, and a major burden of the city administration is the collection and processing of about 50,000 tons of domestic waste daily. Household waste is taken to transfer stations, where it is loaded into bulk containers for transportation to landfill sites. A large proportion of the waste is putrescible and may also contain fecal and other microorganisms from human and animal sources, e.g., from disposable diapers, animal feces.[1] It is, therefore, readily colonized by bacteria and fungi. Handling such waste may result in the dispersal of fungal and actinomycete spores, bacteria, mycotoxins, and endotoxins (lipopolysaccharide from Gram-negative bacterial cell walls) into the air,[2] presenting the risk of inhalation and possible disease both in workers and in the neighboring population. Inhalation of dusts containing microorganisms and their products can result in a range of respiratory symptoms.[3–5] Sometimes, the association between symptoms and a specific agent is clear[6,7] but often many potential causal agents are present. In work environments where organic matter is handled, the risk of allergy (including both asthma and allergic alveolitis) to microorganisms is often greater than that of infection. Allergic alveolitis, particularly, may be associated with exposure to large concentrations of microorganisms (>10^6/m^3 of air) made airborne by work-related activities. Such concentrations usually greatly exceed those normally found in outdoor air.[8]

Economic, political, and environmental constraints often require the siting of municipal solid waste processing plants and sewage treatment plants within urban and suburban areas. However, the proximity of such plants to residential areas may contribute considerably to the airborne microorganism concentrations in these areas.[9,10] Exposure to large concentrations of dust during the handling of domestic waste has previously been reported in other countries.[11–13] Air in waste transfer stations in the United Kingdom has been shown to contain 10^3–10^5 cfu bacteria/m^3 of air, including 10^2–10^3 cfu Gram-negative bacte-

ria/m^3.[11,12] However, exposure of employees and local populations to emissions from waste disposal facilities has never been evaluated in Mexico. There are 15 domestic waste transfer stations operating in Mexico City and another 10 are planned. As with any industrial plant, the potential occupational and environmental health risks associated with the operation of waste treatment plants must be evaluated if methods are to be developed which will minimize related environmental and occupational health problems.

This investigation was designed to measure concentrations of both mesophilic bacteria and fungi in the air during the handling of domestic waste, and to compare these with levels outside the transfer station.

III. MATERIALS AND METHODS

A. WASTE TRANSFER STATION

The site used in this study was a roofed waste transfer station without walls, "Central de Abastos," situated in the northeastern part of Mexico City (Figure 1). The site covers an area of about 900 m^2, where about 2000 tons of waste per day are handled. The area surrounding the station is almost flat, with prevailing wind from the northeast. There is open pasture with small trees to the south and the west, and residential areas to the north and the east. Waste is collected from domestic and commercial premises and taken to the transfer station in specially designed vehicles. At the station the waste is compacted into bulk containers for transport to landfill sites.

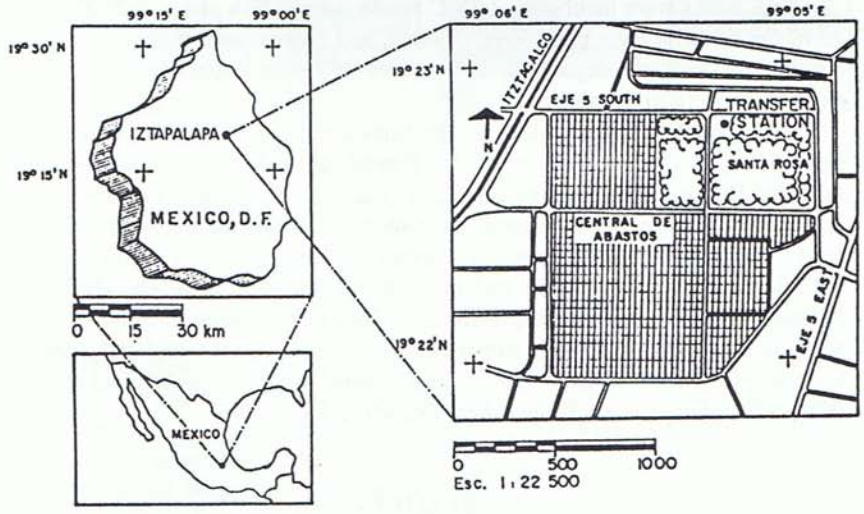

FIGURE 1 Location of sampling site.

B. SAMPLING SITES

Working environment. Sampling sites were selected to represent different work activities. These included:

Inside the station

1. Next to garbage trucks during unloading
2. Next to bulk containers during filling
3. Lunch room

Outside the station

4. 50 m downwind of the station
5. 20 m upwind of the station (Figure 1)

C. AIR SAMPLING

Air was sampled on 12 occasions at each site using two-stage Andersen samplers (Andersen Samplers, Inc., Atlanta, GA). Orifice diameters for stages 1 and 2 were 1.5 and 0.4 mm. The sampler was operated for 5 min at 28.3 l/min, and was mounted on a 2-m high tower, facing into the wind. The Andersen samplers were loaded with plastic Petri dishes containing 20 ml of either trypticase soy agar (TSA) (Difco Laboratories, Inc., Detroit, MI) for bacteria or malt extract agar (MEA) (Difco) for fungi. Meteorological parameters and the atmospheric stability were recorded outside of the station.

TSA plates were incubated at 35°C for 48 h and MEA plates at 25°C for 72 h. Colonies on each plate were counted, and counts were transformed to account for multiple deposition of particles at single impaction sites and expressed as cfu/m^3 of air.[14]

Representative fungal colonies were transferred to Difco potato dextrose agar (*Alternaria, Cladosporium*), Difco Czapek agar (*Penicillium, Aspergillus*), and Difco yeast extract glucose agar (yeast) media[15–17] and incubated at 25°C for 72 h before identification. Each sporulating fungus was identified at least to the genus level. All bacterial colonies were transferred to Oxoid violet red bile glucose agar (VRBG), and incubated at 37°C for 48 h. The suspect *Salmonella* colonies were plated on the selective isolation medium, *Salmonella Shigella* agar (SS agar Difco). Representative colonies from both VRBG and SS agar plates were isolated and identified using standard biochemical tests (ID-GNI Biotest, Biotest Diagnostics, Frankfort, Germany).

IV. RESULTS

At the transfer station, where waste was being handled, all deposition sites on the Andersen sampler plates were frequently occupied, when isolating

bacteria and fungi (Table 1). Where plates were overloaded, colony counts may have been understimates so that geometric mean values are shown as being greater than (>) the indicated value. Geometric mean concentrations of particles carrying one or more viable bacteria at the three sites ranged from 5000–>9100 cfu/m^3 of air and of those carrying Gram-negative bacteria from 170–460 cfu/m^3. Geometric mean concentrations of particles carrying viable fungi ranged from 3700–>9050 cfu/m^3. Of these, 2300–7000 cfu/m^3 were *Penicillium* spp. In general, the temperature during sampling was close to the maximum temperature for the day, with light winds and unstable or neutral conditions (Table 2). Upwind and downwind concentrations were smaller than at the transfer station (Table 1). Upwind, the geometric mean concentrations of bacteria and fungi were 270 and 75 cfu/m^3, respectively. Bacteria and fungi downwind of the transfer station were more numerous (1115 and >1300 cfu/m^3, respectively) than those upwind. Gram-negative bacteria formed a large percentage (14–21%) of the total bacteria at the transfer station sites but only 1–3% outside the station. This was also the case for *Penicillium* which accounts for more than 70% of the total fungal colonies at the transfer station, but for less than 45% outside the station. Usually, more than 50% of *Penicillium* cfu were in the respirable fraction (lower stage of the Andersen sampler) (Figure 2) at both transfer station and downwind sampling sites, while most Gram-negative bacteria were in the nonrespirable fraction (top stage).

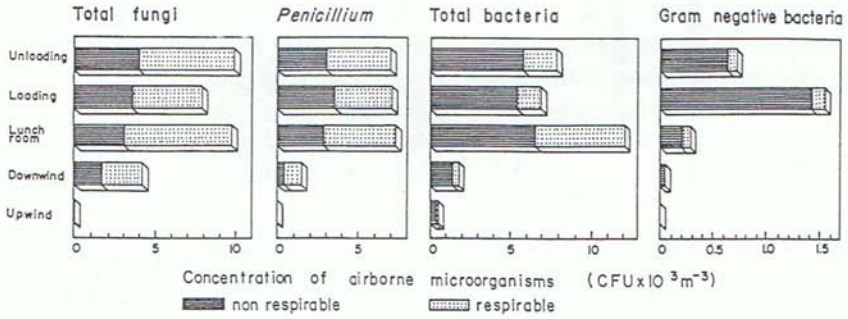

FIGURE 2 Concentration (arithmetic mean) of respirable and nonrespirable fungi *Penicillium*, total Bacteria, and Gram-negative bacteria.

The different genera of fungi that were isolated are listed in Table 3. *Penicillium* was usually the predominant colony type. However *Alternaria* and *Cladosporium* were also frequently isolated at the upwind site. Also listed in Table 3 are genera of Gram-negative bacteria that were isolated. *Enterobacter* predominated, being present in 78% of samples and forming 18% of the total Gram-negative bacteria counted. *Salmonella* was isolated from 14% of air samples in the transfer station but was found in small numbers only. Suggested limit values for concentrations of bacteria[18,19] of 2500 and 5000 cfu/m^3 of air

TABLE 1 Airborne Concentrations of Microorganisms (cfu/m³), in and around a Transfer Station

Sampling Station	Number of Samples	Total Bacteria		Gram-negative Bacteria		
		Range	Geometric Mean	Range	Geometric Mean	Percentage of Total
Unloading trucks	12	2,200–14,800[a]	>6,700	11–3,920	>270	14
Loading containers	12	350–14,800[a]	>5,000	11–4,480	>460	21
Lunch room	12	2,220–14,800[a]	>9,100	21–1,280	>170	3
Downwind	12	270–4,220	1,115	0–200	—	3
Upwind	12	60–740	270	0–14	—	1

		Mesophilic Fungi		*Penicillium*		
		Range	Geometric Mean	Range	Geometric Mean	Percentage of Total
Unloading trucks	12	170–14,800[a]	>4,900	28–14,800[a]	>2,300	70
Loading containers	12	340–14,800[a]	>3,700	63–14,800[a]	>2,650	75
Lunch room	12	6,020–14,800[a]	>9,050	95–14,800[a]	>7,000	79
Downwind	12	165–14,800[a]	>1,300	22–6,450	320	35
Upwind	12	20–175	75	4–100	15	45

[a] Maximum concentration threshold of Andersen sampler exceeded; geometric means are underestimates.

TABLE 2 Meteorological Parameters and Atmospheric Stability during the Sampling Period

Date	Air Temperature	Daytime Max. Temp. (°C)	Relative Humidity (%)	Wind Speed (m/s)	Atmospheric Stability Index[26]
22 Aug 89	25	26	51.4	0	1
28 Aug 89	22	25	60.0	0	2
06 Sep 89	22	22	55.1	0	2
19 Sep 89	21	22	71.7	4	3
29 Sep 89	20	22	52.5	3	2
11 Oct 89	22	22	43.5	4	3
19 Oct 89	15	17.5	60.7	0	4
27 Oct 89	21	26	47.8	0	2
06 Nov 89	22	27.5	48.8	2	2
14 Nov 89	23	26.8	39.6	0	2
23 Nov 89	17	20	62.4	2	4
01 Dec 89	17	21.2	55.8	2	4

were exceeded in 90 and 25% of samples, respectively (Figure 3), and limit values of Gram-negative bacteria[2] of 1000 cfu/m^3 were exceeded in 35% of samples.

V. DISCUSSION

This survey shows that a range of bacteria and fungi can be aerosolized when handling domestic waste. Many of the reported concentrations, especially in the transfer station are underestimates due to overloading of the Andersen plates.[20] Also, sampling was usually done during maximum daytime temperatures, when atmospheric conditions are most unstable, which could also affect recoveries.

To evaluate the contamination levels of these sampling sites, it is necesary to compare the results with published standards. Boutin et al.[18] suggested an upper limit of 2500 cfu airborne bacteria/m^3 of air was acceptable. However, 5000 cfu/m^3 has been recommended as a level indicating an abnormal source of bacteria in indoor environments.[19] With respect to Gram-negative bacteria, Rylander et al.,[2] studying endotoxin and related symptoms among compost workers, suggested a maximum of 1000 Gram-negative cfu/m^3 for safe working conditions. A large proportion of the concentrations measured within the transfer station exceeded these standards, indicating a high level of contamination.

Respiratory symptoms, abdominal pains, and diarrhea have often been reported by domestic waste transfer station workers.[11,21] These symptoms can be caused by Gram-negative bacteria, such as *Enterobacter cloacae*, *Escherichia coli*, and *Citrobacter freundii*, which have been shown to be toxic to experimental animals inhaling 2.5×10^9 bacteria/m^3, over a 40-min exposure

TABLE 3 Isolation and Abundance of Identified Gram-Negative Bacteria and Fungi in Air Samples from the Transfer Station

Genera	Frequency of Isolation (%)[a]			Abundance (cfu/m³)[b]		
	Station[c]	Downwind	Upwind	Station[c]	Downwind	Upwind
Fungi						
Alternaria	5	17	100	2	4	20
Aspergillus	47	42	92	393	34	11
Cladosporium	17	75	83	36	400	14
Monilia	95	100	33	54	40	1
Penicillium	100	100	100	7760	2975	21
Rhizopus	78	67	17	40	32	1
Yeasts	22	42	8	262	89	1
Others	36	83	17	259	672	7
Bacteria						
Acinetobacter	70	42	—	124	7	—
Actinobacillus	17	25	—	42	2	—
Alcaligenes	39	25	20	33	2	0.2
Citrobacter	44	18	—	74	3	—
Enterobacter	78	55	20	163	12	0.5
Escherichia	58	42	20	91	6	0.2
Flavobacterium	31	8	20	36	1	0.5
Hafnia	44	33	40	11	3	1
Klebsiella	28	17	—	30	1	—
Proteus	8	—	—	14	—	—
Pseudomonas	22	8	—	16	1	—
Salmonella	14	—	—	7	—	—
Serratia	50	18	—	91	5	—
Yersinia	25	—	—	19	—	—
Others	61	25	10	103	6	0.5

[a] Percentage of samples containing each taxon.
[b] Concentration (arithmetic mean) of isolates classified within each taxon.
[c] Average of the 3 sampling sites located in the station.

period.[22,23] All three species were frequently isolated from the air of the transfer station. Moreover, enteropathogenic bacteria, such as *Salmonella*, were recovered from 14% of samples collected close to the lunch room. Its occurrence may have been related to the handling of diapers, which formed 20–30% of the bulk of the domestic waste.

Since particle size plays an important role in lung penetration and retention, the aerodynamic sizes of particles were deduced from the distribution of colonies recovered in the two-stage Andersen sampler. In general, 50 to 60% of fungal-containing particles, including *Penicillium*, were collected on the lower stage and were of a size that could penetrate into the lower airways.[24] This result was similar to that of another study done in houses.[25] Moreover *Penicillium*, a potential allergen, comprised 75% of the total airborne fungi collected during the handling of the waste. Because of the high concentrations found, we think that these bioaerosols probably constitute a risk to the health of the workers at the station and of the neighboring population.

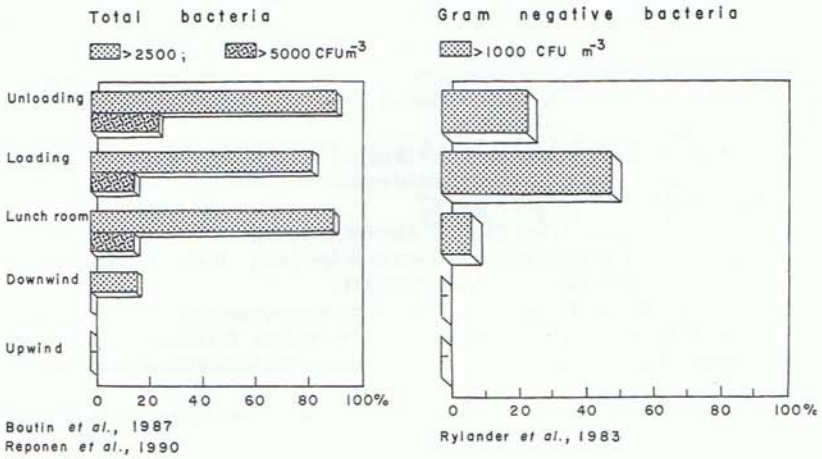

FIGURE 3 Occurrence of airborne concentration exceeding 2500 and 5000 total bacteria or 1000 Gram-negative bacteria/m^3 of air.

ACKNOWLEDGMENTS

This work was partially supported by the Departamento del Distrito Federal, Dirección Técnica de Desechos Sólidos and Programa Universitario de Investigacion en Salud. We are grateful to Mr. José Juan Morales Reyes, Mrs. Alma Luz Yela Miranda, and Mr. Alfredo Rodríguez for their technical assistance.

REFERENCES

1. Peterson, M., Soiled disposable diapers: a potential source of virus, *Am. J. Public Health*, 64, 912, 1974.
2. Rylander, R., Lundholm, M., and Clark, C.S., Exposure to aerosols of micro-organisms and toxins during handling of sewage sludge, in *Biological Health Risk of Sludge Disposal to Land in Cold Climates*, Wallis, P.M. and Lohmann, D.L., Eds., University of Calgary Press, Alberta, Canada, 1983, 69.
3. Forster, H.W., Crook, B., Platts, B.W., Lacey, J., and Topping, M.D., Investigation of organic aerosols generated during sugar beet slicing, *Am. Ind. Hyg. Assoc.*, 50, 44, 1989.
4. Rosas, I., Gutierrez, S., Yela, A., Selman, M., Teran, L., and Mendoza, A., Respuesta de los trabajadores a los microorganismos suspendidos en la atmosfera de una fabrica de papel, *Arch. Invest. Med.*, 19, 23, 1988.
5. Rylander, R., Lung diseases caused by organic dust in the farm environment, *Am. J. Ind. Med.*, 10, 221, 1986.
6. Lacey, J. and Crook, B., Fungal and actinomycete spores as pollutants of the work place and occupational allergens, *Ann. Occup. Hyg.*, 32, 515, 1988.
7. Pepys, J., Jenkins, P., Festenstein, G., Gregory, P.H., Lacey, M.E., and Skinner, F., Farmer's lung, thermophilic actinomycetes as a source of "farmer's lung, hay antigen," *Lancet*, 2, 607, 1963.

8. Lacey, J., Pepys, J., and Cross, T., Actinomycete and fungus spores in air as respiratory allergens, in *Safety in Microbiology*, Shapton, D.A. and Board, R.G., Eds., Society for Applied Bacteriology Technical Series No. 6, Academic Press, London, 1972, 151.
9. Fannin, K., Vana S., and Jakubowski, W., Effect of an activated sludge wastewater treatment plant on ambient air densities of aerosol containing bacteria an viruses, *Appl. Environ. Microbiol.*, 49, 1191, 1985.
10. Millner, P., Basset, D., and Marsh, P., Dispersal of *Aspergillus fumigatus* from sewage sludge compost piles subject to mechanical agitation in open air, *Appl. Environ. Microbiol.*, 39, 1000, 1980.
11. Crook, B., Higgins, S., and Lacey, J., Airborne Gram negative bacteria associated with the handling of domestic waste, in *Advances in Aerobiology*, Boehm, G. and Leuschner, R.M., Eds., Birkhauser Verlag, Basel, 1987, 371.
12. Crook, B., Bardos, P., and Lacey, J., Domestic waste composting plants as source of airborne micro-organisms, in *Aerosols: Their Generation, Behaviour and Application*, Griffiths, W.D., Ed., Aerosol Society 2nd Conference, The Aerosol Society, London, 1988, 63.
13. Lembke, L. and Kniseley, R., Airborne microorganisms in a municipal solid waste recovery system, *Can. J. Microbiol.*, 31, 198, 1985.
14. Andersen, A.A., New sampler for the collection, sizing, and enumeration of viable airborne particles, *J. Bacteriol.*, 76, 71, 1958.
15. Dhingra, O.D. and Sinclair, J.B., *Basic Plant Pathology Methods*, CRC Press, Inc., Boca Raton, FL, 1985, 355.
16. Pitt, J., *A Laboratory Guide to Common Penicillium Species*, Commonwealth Scientific and Industrial Research Organization, Division of Food Research, North Ryde, Australia, 1985, 184.
17. Raper, K. and Fennel, D., *The Genus Aspergillus*, R.E. Klieger, New York, 1977, 686.
18. Boutin, P., Torre, M., Moline, J., and Boissinot, E., Bacterial atmospheric contamination in wastewater treatment plants, in *Advances in Aerobiology*, Boehm, G. and Leuschner, R.M. Eds., Birkhauser Verlag, Basel, 1987, 365.
19. Reponen, T., Nevalainen, A., Jantunen, M., Pellikka, M., and Kalliokoski, P., Normal range criteria for indoor air bacteria and fungal spores in a subartic climate, *Indoor Air*, 2, 26, 1992.
20. Gillespie, V.L., Clark, C.S., Bjornson, H.S., Samuels, S.J., and Holland, J.W., A comparison of two-stage and six-stage Andersen impactors for viable aerosols, *Am. Ind. Hyg. Assoc.*, 42, 858, 1981.
21. Lundholm, M. and Rylander, R., Occupational symptoms among compost workers, *J. Occup. Med.*, 22, 256, 1980.
22. Baseler, M., Fogelmark, B., and Burrel, R., Differential toxicity of inhaled Gram negative bacteria, *Infect. Immun.*, 40, 133, 1983.
23. Clark, S., Rylander, R., and Larsson, L., Levels of Gram negative bacteria, *Aspergillus fumigatus*, dust and endotoxin at compost plants, *Appl. Environ. Microbiol.*, 45, 1501, 1983.
24. Rantio-Lehtimaki, A., Evaluating the penetration of *Cladosporium* spores into the human respiratory system on the basis of aerobiological sampling results, *Allergy*, 44, 18, 1989.
25. Flannigan, B., McCabe, E.M., and McGarry, F., Allergenic and toxigenic micro-organisms in houses, *J. Appl. Bacteriol. Symp. Suppl.*, 70, 61 S, 1991.
26. Turner, D.B., A diffusion model for an urban area, *J. Appl. Met.*, 3, 83, 1964.

Formato para cita:

(Rosas, Calderón, Salinas, & Lacey, 1996)

Formato para Referencia Bibliográfica:

Rosas, I., Calderón, C., Salinas, E., & Lacey, J. (1996). Airborne Microorganisms in a Domestic Waste Transfer Station. En M. Muilenberg, H. Burge, & P.-A. A. Association (Ed.), *Aerobiology: proceedings of Pan-American Aerobiology Association* (págs. 89-98). Boca Raton, Florida, USA: CRC Press, Inc.