
A summary of the atmospheric surveys published in the United States allergy literature, 1966–1996

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Objective: In this investigation we sought to summarize the atmospheric surveys that were published in two United States allergy journals (and subsequent series) during a 31-year period beginning in 1966.

Data sources: All original articles published in the *Annals of Allergy* (and its subsequent series) and the *Journal of Allergy* (and its subsequent series) were cataloged in a computer database beginning with the first issues of 1966. Publications were classified in a manner reflecting their aerobiologic content.

Study selection: From this database of articles (n = 7,403), atmospheric surveys for pollen, spores, and other aeroflora were identified and summarized according to standard criteria. For each study we documented the sampling instruments used, the height of these instruments off of the ground, the study period, and the sampling schedule.

Results: Sixty-one atmospheric surveys were summarized: 30 from locations in the United States and 31 from outside of the country. Various volumetric and nonvolumetric samplers were used; the height of instruments above the ground and the sampling protocols varied widely.

Conclusions: This investigation can serve as a companion to earlier compilations. These data should prove more useful than information available via electronic and paper indexes.

Ann Allergy Asthma Immunol 1999;82:543–547.

INTRODUCTION

Because of the medical significance of pollen and spores, atmospheric surveys and pollen calendars for various cities have frequently been published in the United States allergy literature. An extensive catalog of the investigations conducted through the early 1940s was supplied by Gottlieb and Urbach.¹ Samter and Durham,² Newmark,^{3,4} Wodehouse,⁵ and Lewis et al⁶ summarized some subsequent developments. To our knowledge, however, a systematic treatment of surveys appearing in recent decades does not exist.

The purpose of this present investigation was to identify atmospheric sur-

veys that were published in two allergy journals (and subsequent series) during a 31-year period beginning in 1966. Our findings are presented here to assist allergists and allied scientists interested in aerobiology.

MATERIALS AND METHODS

All original articles and reviews appearing in the *Annals of Allergy* (n = 2,897); *Annals of Allergy, Asthma and Immunology* (n = 255); *Journal of Allergy* (n = 290); and the *Journal of Allergy and Clinical Immunology* (n = 3,961) were cataloged in a computer database (FileMaker Pro 2.0; Claris Corporation, Santa Clara, CA) beginning with the first issues of 1966 (volumes 26 and 38 of the first and third titles, respectively). Publications were classified in a manner reflecting their aerobiologic content.

From this database, atmospheric surveys for pollen, spores, and other

aeroflora were identified and summarized according to standard criteria. For each study we documented the sampling instruments used, the height of these instruments off of the ground, the study period, and the sampling schedule.

Investigations such as drug studies that contained minor aerobiologic dimensions (eg, pollen or spore counts) were excluded from consideration. Studies dealing with indoor allergens also fell outside the purview of our effort.

RESULTS AND DISCUSSION

Sixty-one atmospheric surveys were published during the period reviewed. Thirty investigations were performed in cities in the United States and 31 studies were conducted outside of the country. More investigations were published in the *Annals of Allergy* and its subsequent series (n = 50) than the *Journal of Allergy* and its subsequent series (n = 11).

Of the domestic investigations, 17 used volumetric instruments to obtain atmospheric samples (Table 1). The Rotorod Sampler^{7–9} was most commonly used (n = 6) followed by the Burkard spore trap (n = 5), the commercial version of the sampler developed by Hirst.¹⁰ Other investigations used the Rotoslide,^{11,12} Rotobar,¹³ Kramer-Collins spore sampler^{14,15} and the Andersen sampler.¹⁶ The first two devices resemble the Rotorod Sampler while the third instrument is similar to the Burkard spore trap. The Andersen sampler uses a cascading strategy to impinge particles of different sizes on plates containing culture medium.

Of the remaining domestic efforts, 13 used nonvolumetric instruments

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Received for publication August 31, 1998.

Accepted for publication in revised form February 2, 1999.

Table 1. Atmospheric Surveys Conducted in the United States Including the Device Used, Height of the Device Off of the Ground, and Sampling Parameters

State	City	Ref	Topic*	Device**	Height	YS†	SP‡	SF§
AL	Birmingham	20	P, S	F, G, RS	—	1965–66	—	—
AK	Anchorage	21	P, S	B	25 m	1982–83	24 h	7 d/w
	Fairbanks	22	P, S	B, D	multiple	1978, 81–82	24+ h	various
AZ	Phoenix	23	S	CP	3 ft	1964–65	15 min	3/w
	Tucson	24	S	CP	—	1964–65	15 min	3/w
	Tucson	25	S	G	—	1960–80	daily	5–6 d/w
	Tucson	26	P	D	—	since 1943	daily	5 d/w
CA	Desert areas	27	S	CP	—	1981–82	15 min	weekly
	San Diego	28	P, S	RR	3.9 m	1973–74	24 h	—
	San Francisco	29	P	RS	multiple	1973–81	48 h	1/w
	San Luis Obispo	30	P, S	RR	14.6 m	1986–88	24 h	1/w
	Ventura	31	P, S	D	13 ft	1970–71	48 h	2/w
CO	Aspen, Denver, Vail	32	P	RR	2nd story	1984–88	24 h	2–5 d/w
	Gothic	33	P, S	RR	—	1981–83	daily	daily
DC	Washington	34	P, S	CP, D	3rd story	1977	various	various
	Washington	35	P, S	A, CP, D	multiple	1981	various	various
FL	Hollywood	36	P, S	D	3rd story	1973–74	1 w	1/w
	Tampa Bay	37	P	RS	3rd story	1979–81	24+ h	daily
KS	Manhattan	38	S	KC	2 ft	1968–69	2.5 min	24/d
LA	New Orleans	39	S	CP, RS	multiple	1967–68	various	various
MI	Ann Arbor	40	P	B, D, RB	50 ft	1968–72	various	various
NM	Albuquerque	41	S	CP	—	1965–66	15 min	3/w
OK	Tulsa	42	S	CP	—	1976	10 min	5/m
TX	Corpus Christi	43	P	B	1.6 m	1987–89	24 h	7 d/w
	Corpus Christi	44	P	B	1.6 m	1987–89	24 h	7 d/w
	San Antonio	45	S	CP	multiple	1965	5 min	5 d/w
WA	Walla Walla	46	P	RR	—	1975–76	20 min	2/d
—	Multiple (5)	47	S	CP	60 cm	1971–72	various	2/w
—	Multiple (14)	48	S	CP	—	1978–81	15 min	2/m
—	Multiple (23)	49	P	RR, RS	—	various	—	—

* P = pollen, S = spores.

** A = Andersen sampler, B = Burkard spore trap, CP = Culture plate method, D = Durham sampler, G = Gravity sampler, F = Flag sampler, KC = Kramer-Collins spore sampler, RB = Rotobar sampler, RR = Rotorod Sampler, and RS = Rotoslide sampler.

† Years sampled.

‡ Sampling period: the duration of each sample.

§ Sampling frequency: how often samples were obtained.

|| Included San Jose.

(Durham sampler,¹⁷ gravity samplers, and culture plate methods) as the sole means to obtain atmospheric samples. These studies were performed primarily in the 1960s and 1970s before volumetric devices were widely used for routine aeroallergen sampling. Because of the well-known limitations of these sampling strategies,^{18,19} data from these investigations should be interpreted with great caution.

For volumetric surveys performed outside of the United States, investigators primarily used the Burkard spore trap (n = 5) or the Lanzoni (n = 2), its Italian counterpart, to obtain atmo-

spheric samples (Table 2). Only one investigation presented data collected with the Rotorod Sampler; another study employed a Casella bacteria sampler.

The majority of surveys were conducted with nonvolumetric instruments (n = 21). Like their domestic counterparts, these studies were typically performed during the early period that we reviewed. All published data collected after 1982 were obtained with volumetric devices.

Tables 1 and 2 contain tabulations of standard parameters for the various surveys. Regrettably, a number of in-

vestigators did not fully describe the height and position of their instruments and sampling protocols. Absence of such information hampers the interpretation of their data and precludes ready comparison with the results of other investigations.

This present summary, when combined with other compilations,^{1–6} provides a convenient means for allergists and aerobiologists to locate atmospheric surveys conducted in many cities in the United States and other countries. These data should prove more useful than information available via electronic and paper indexes.

Table 2. Atmospheric Surveys Conducted in Locations Outside of the United States Including the Device Used, Height of the Device Off of the Ground, and Sampling Parameters

Country	City	Ref	Topic*	Device**	Height	YS†	SP‡	SF§
Antarctica	McMurdo	50	P, S	G	–	1970–71	days	–
Canada	Toronto	51	P	D	8th story	1971	24 h	daily
	Toronto	52	S	CP, D	8th story	1971	24 h	daily
China	Nanning	53	P	D	multiple	1980–82	24 h	–
Columbia	Bogota	54	P	G	15 m	1959–64	daily	daily
Egypt	Cairo	55	S	CP	15 ft	1964	24 h	daily
India	Bangalore	56	P	RR, VC	multiple	1979	various	various
	Dehra Dun	57	P, S	AS	12 m	1980–81	24 h	7 d/w
	Delhi	58	S	CP, G	10 m	1965–66	various	various
	Delhi	59	A	D, G	multiple	1972–74	24 h	
	Delhi	60	P	D	–	1973–75	–	–
	Madras	61	S	B	10 m	1981–82	–	–
Iran	Ahwas	62	S	CP	–	1976	30 min	3/w
	Shiraz	63	P	D	–	1976	24 h	daily
	Shiraz	64	S	D	–	1977	24 h	daily
	Tehran	65	P	D	3rd story	1974–75	24 h	daily
	Tehran	66	S	CP	3rd story	1974–75	20 min	14/w
Iraq	Baghdad	67	P, S	CP	–	1975	–	¶
Israel	Arad	68	P, S	CP, D	multiple	1963–64	various	various
	Arad	69	S	CABS	2–3 m	1973–74	2 min	††
Italy	Ascoli Piceno	70	P	B	–	1981–84	24 h	7 d/w
	Bari	71	P	B	20 m	1982–89	24 h	7 d/w
	Cagliari	72	P, S	L	20 m	1986–88	–	–
	Mediterranean	73	P	L	25 m	1979–87	24 h	7 d/w
	Naples	74	S	B	25 m	1980–82	24 h	7 d/w
Nigeria	Zaria	75	S	CP	multiple	1980–81	10 min	1/w
Philippines	–	76	P	D	multiple	1972–73	48 h	–
Spain	Barcelona	77	S	‡‡	–	1976–78	4 min	–
	Madrid	78	P	B, H	20 m	1979–93	24 h	7 d/w
Thailand	Bangkok	79	P, S	D	–	1972–74	24 h	daily
	Bangkok	80	S	CP	–	1976–77	15 min	1/w

* A = algae, P = pollen, and S = spores.

** AS = aeroscope, B = Burkard spore trap, CABS = Casella airborne bacteria sampler, CP = Culture plate method, D = Durham sampler, G = Gravity sampler, H = Hirst spore trap, L = Lanzoni VPPS 2000, RR = Rotorod Sampler, and VC = Vertical cylinder.

† Years sampled.

‡ Sampling period: the duration of each sample.

§ Sampling frequency: how often samples were obtained.

|| All working days.

¶ Bimonthly.

†† Every other day.

‡‡ Unspecified volumetric instrument that impinged samples on culture medium.

REFERENCES

- Gottlieb PM, Urbach E. The distribution and pollination times of the most important hay fever-producing plants in the United States. *J Lab Clin Med* 1943;28:1053–1070.
- Samter M, Durham OC, eds. Regional allergy of the United States, Canada, Mexico and Cuba. Springfield: Charles C. Thomas Publisher, 1955.
- Newmark FM. Pollen aerobiology—the need for research and compilation. *Ann Allergy* 1968;26:358–373.
- Newmark FM. Recent developments in pollen aerobiology. *Ann Allergy* 1970;28:149–152.
- Wodehouse RP. Hayfever plants, 2nd ed. New York: Hafner Publishing Co, 1971:190–252.
- Lewis WH, Vinay P, Zenger VE. Airborne and allergenic pollen of North America. Baltimore: Johns Hopkins University Press, 1983.
- Perkins WA. The Rotorod Sampler: second semiannual report (Aerosol Laboratory, CML 186). Stanford: Stanford University, 1957.
- Magill PL, Lumpkins ED, Arveson JS. A system for appraising airborne populations of pollens and spores. *Am Ind Hyg Assoc J* 1968;29:293–298.
- Frenz DA, Lince NL. A comparison of pollen recovery by three models of the Rotorod Sampler. *Ann Allergy Asthma Immunol* 1997;79:256–258.
- Hirst JM. An automatic volumetric spore trap. *Ann Appl Biol* 1952;39:257–265.
- Ogden EC, Raynor GS. A new sampler for airborne pollen: the roto-slide. *J Allergy* 1967;40:1–11.
- Raynor GS, Ogden EC. The swing-

- shield: an improved shielding device for the intermittent rotoslide sampler. *J Allergy* 1970;45:329–332.
13. Solomon WR, Stohrer AW, Gilliam JA. The “fly-shield” rotobar: a simplified impaction sampler with motion-regulated shielding. *J Allergy* 1968;41:290–296.
14. Kramer CL, Pady SM. A new 24-hour spore sampler. *Phytopathology* 1966;56:517–520.
15. Kramer CL, Eversmeyer MG, Collins TI. A new 7-day spore sampler. *Phytopathology* 1976;66:60–61.
16. Andersen AA. New sampler for collection, sizing, and enumeration of viable airborne particles. *J Bacteriol* 1958;76:471–484.
17. Durham OC. The volumetric incidence of atmospheric allergens: IV. A proposed standard method of gravity sampling, counting and volumetric interpolation of results. *J Allergy* 1946;17:79–86.
18. Gregory PH. The microbiology of the atmosphere, 2d ed. New York: John Wiley and Sons, 1973:13, 128.
19. Ogden EC, Raynor GS, Hayes JV, et al. Manual for sampling airborne pollen. New York: Hafner Press, 1974:40–70.
20. Stalker WW, Moore PM. Air-borne pollen and fungal spore patterns in the Birmingham, Alabama, area. *Ann Allergy* 1972;30:326–334.
21. Anderson JH. Allergenic airborne pollen and spores in Anchorage, Alaska. *Ann Allergy* 1985;54:390–399.
22. Anderson JH. A survey of allergenic airborne pollen and spores in the Fairbanks area, Alaska. *Ann Allergy* 1984;52:26–31.
23. Goodman DH, Northey WT, Leathers CR, Savage TH. A study of airborne fungi in the Phoenix, Arizona, metropolitan area. *J Allergy* 1966;38:56–62.
24. Dworin M. A study of atmospheric mold spores in Tucson, Arizona. *Ann Allergy* 1966;24:31–36.
25. Sneller MR, Hayes HD, Pinnaas JL. Frequency of airborne *Alternaria* spores in Tucson, Arizona over a 20-year period. *Ann Allergy* 1981;46:30–33.
26. Sneller MR, Hayes HD, Pinnaas JL. Pollen changes during five decades of urbanization in Tucson, Arizona. *Ann Allergy* 1993;71:519–524.
27. Caplin I, Unger DL. Molds on the southern California deserts. *Ann Allergy* 1983;50:260–263.
28. Street DH, Hamburger RN. Atmospheric pollen and spore sampling in San Diego, California: I. Meteorological correlations and potential clinical relevance. *Ann Allergy* 1976;37:32–40.
29. Fairley D, Batchelder GL. A study of oak-pollen production and phenology in northern California: prediction of annual variation in pollen counts based on geographic and meteorologic factors. *J Allergy Clin Immunol* 1986;78:300–307.
30. McLean AC, Parker L, von Reis J, von Reis J. Airborne pollen and fungal spore sampling on the central California coast: the San Luis Obispo pollen project. *Ann Allergy* 1991;67:441–447.
31. Villaveces JW. A survey of allergenic plants and pollens in Ventura, California. *Ann Allergy* 1972;30:203–207.
32. Silvers WS, Ledoux RA, Dolen WK, et al. Aerobiology of the Colorado Rockies: pollen count comparisons between Vail and Denver, Colorado. *Ann Allergy* 1992;69:421–426.
33. Buck P, Levetin E. Airborne pollen and mold spores in a subalpine environment. *Ann Allergy* 1985;55:794–801.
34. Al-Doory Y, Domson JF, Howard WA, Sly RM. Airborne fungi and pollens of the Washington, DC, metropolitan area. *Ann Allergy* 1980;45:360–367.
35. Al-Doory Y, Domson JF, Best J. Further studies of the airborne fungi and pollens of the Washington, DC metropolitan area. *Ann Allergy* 1982;49:265–269.
36. Finegold I. A two-year pollen and spore survey of southeast Florida. *Ann Allergy* 1975;35:37–41.
37. Bucholtz GA, Lockey RF, Wunderlin RP, et al. A three year aerobiologic survey of the Tampa Bay area, Florida. *Ann Allergy* 1991;67:534–540.
38. Long DL, Kramer CL. Air spora of two contrasting ecological sites in Kansas. *J Allergy Clin Immunol* 1972;49:255–266.
39. Salvaggio J, Seabury J. New Orleans asthma: IV. Semiquantitative airborne spore sampling, 1967 and 1968. *J Allergy Clin Immunol* 1971;48:82–95.
40. Solomon WR. Volumetric studies of aeroallergen prevalence: I. Pollens of weedy forbs at a midwestern station. *J Allergy Clin Immunol* 1976;57:318–327.
41. Dupont EM, Field RC, Leathers CR, Northey WT. A survey of the airborne fungi in the Albuquerque, New Mexico, metropolitan area. *J Allergy* 1967;39:238–244.
42. Levetin E, Horowitz L. A one-year survey of the airborne molds of Tulsa, Oklahoma: I. Outdoor survey. *Ann Allergy* 1978;41:21–24.
43. Lewis WH, Dixit AB, Wedner HJ. Asteraceae aeropollen of the western United States Gulf Coast. *Ann Allergy* 1991;67:37–46.
44. Lewis WH, Dixit AB, Wedner HJ. Aeropollen of weeds of the western United States Gulf Coast. *Ann Allergy* 1991;67:47–52.
45. Al-Doory Y. Further studies of the fungal flora of the air in San Antonio, Texas. *J Allergy* 1967;40:145–150.
46. Anderson EF, Dorsett CS, Fleming EO. The airborne pollens of Walla Walla, Washington. *Ann Allergy* 1978;41:232–235.
47. Sorenson WG, Bulmer GS, Crip LH. Airborne fungi from five states in the continental United States and Puerto Rico. *Ann Allergy* 1974;33:131–137.
48. Meyer GH, Prince HE, Raymer WJ. Airborne fungi—a resurvey. *Ann Allergy* 1983;51:26–29.
49. Frenz DA, Palmer MA, Hokanson JM, Scamehorn RT. Seasonal characteristics of ragweed pollen dispersal in the United States. *Ann Allergy Asthma Immunol* 1995;75:417–422.
50. Newmark FM, Salley AM. Gravity slide study at McMurdo Station, Antarctica. *Ann Allergy* 1972;30:67–68.
51. Collins-Williams C, Kuo HK, Varga EA, et al. Atmospheric pollen counts in Toronto, Canada, 1971. *Ann Allergy* 1973;31:65–68.
52. Collins-Williams C, Kuo HK, Garey DN, et al. Atmospheric mold counts in Toronto, Canada, 1971. *Ann Allergy* 1973;31:69–71.
53. Ke C, Jintan Z. A study of aeroallergens in Nanning, Guangxi, China. *Ann Allergy* 1985;54:242–244.
54. Medina MS, Fernandez A. Allergenic pollens in Bogota, Columbia, South America. *J Allergy* 1966;38:46–50.
55. Youssef YA, El-Tarabishy NM. Studies on the atmospheric fungal flora in Cairo. *Ann Allergy* 1966;24:349–354.
56. Seetharamiah AM, Viswanath B, Rao PVS. Atmospheric survey of pollen of *Parthenium hysterphorus*. *Ann Allergy* 1981;47:192–196.
57. Singh BP, Singh AB, Nair PKK, Gan-

- gal SV. Survey of airborne pollen and fungal spores at Dehra Dun, India. *Ann Allergy* 1987;59:229–234.
58. Agarwal MK, Shivpuri DN, Mukerji KG. Studies on the allergenic fungal spores of the Delhi, India, metropolitan area. *J Allergy* 1969;44:193–203.
 59. Mittal A, Agarwal MK, Shivpuri DN. Studies on allergenic algae of [the] Delhi area: botanical aspects. *Ann Allergy* 1979;42:248–252.
 60. Singh AB, Babu CR. Survey of atmospheric pollen allergens in Delhi: seasonal periodicity. *Ann Allergy* 1982;48:115–122.
 61. Vittal BPR, Krishnamoorthi K. A census of airborne mold spores in the atmosphere of the city of Madras, India. *Ann Allergy* 1988;60:99–101.
 62. Hariri AR, Ghahary A, Naderinasab M, Kimberlin C. Airborne fungal spores in Ahwaz, Iran. *Ann Allergy* 1978;40:349–352.
 63. Amin R, Bokhari MH. Survey of atmospheric pollens in Shiraz, Iran—1976. *Ann Allergy* 1977;39:192–195.
 64. Amin R, Bokari MH. Survey on atmospheric fungus spores in Shiraz, Iran (1977). *Ann Allergy* 1979;42:246–247.
 65. Shafiee A. Studies of atmospheric pollen in Tehran, Iran, 1974–75. *Ann Allergy* 1976;37:133–137.
 66. Shafiee A, Rahmani T. Atmospheric mold spores in Tehran, Iran. *Ann Allergy* 1978;40:138–142.
 67. Al-Tikriti SK, Al-Salihi M, Gaillard GE. Pollen and mold survey of Baghdad, Iraq. *Ann Allergy* 1980;45:97–99.
 68. Kantor SZ, Frank M, Hoch-Kantor D, et al. Airborne allergens and clinical response of asthmatics in Arad, a new town in a desert area in Israel. *J Allergy* 1966;37:65–74.
 69. Barkai-Golan R, Frank M, Kantor D, et al. Atmospheric fungi in the desert town of Arad and in the coastal plain of Israel. *Ann Allergy* 1977;38:270–274.
 70. Nardi G, Demasi O, Marchegiani A, et al. A study on airborne allergenic pollen content in the atmosphere of Ascoli Piceno. *Ann Allergy* 1986;57:193–197.
 71. Caiaffa MF, Macchia L, Strada S, et al. Airborne Cupressaceae pollen in Southern Italy. *Ann Allergy* 1993;71:45–50.
 72. Cosentino S, Pisano PL, Fadda ME, Palmas F. Pollen and mold allergy: aerobiologic survey in the atmosphere of Cagliari, Italy (1986–1988). *Ann Allergy* 1990;65:393–400.
 73. D'Amato G, Lobefalo G. Allergenic pollens in the southern Mediterranean area. *J Allergy Clin Immunol* 1989;83:116–122.
 74. D'Amato G, Stanziola AA, Cocco G, Melillo G. Mold allergy: A three year investigation (1980–1982) of the airborne fungal spores in Naples, Italy. *Ann Allergy* 1984;52:363–367.
 75. Lawande RV, Onymelukwe GC. Airborne fungi during harmattan in Zaria, Nigeria. *Ann Allergy* 1984;52:47–49.
 76. Cua-Lim F, Payawal PC, Laserna G. Studies on atmospheric pollens in the Philippines. *Ann Allergy* 1978;40:117–123.
 77. Calvo MA, Guarro J, Suarez G, Ramirez C. Airborne fungi in the air of Barcelona, Spain: V. The yeasts. *Ann Allergy* 1980;45:115–116.
 78. Subiza J, Jerez M, Jiménez JA, et al. Allergenic pollen and pollinosis in Madrid. *J Allergy Clin Immunol* 1995;96:15–23.
 79. Tuchinda M, Theptaranon Y. Aeroallergens in Bangkok, Thailand. *Ann Allergy* 1976;37:47–54.
 80. Bunnang C, Dhorrarintra B, Plangpatanapanichya A. A comparative study of the incidence of indoor and outdoor mold spores in Bangkok, Thailand. *Ann Allergy* 1982;48:333–339.

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