Environment Protection Engineering

Vol. 39 2013 No. 4

DOI: 10.5277/epe130409

ALIAKBAR ROODBARI[1], KAZEM NADDAFI[2], ALLAHBAKHSH JAVID[1]

MEASUREMENTS OF BIOAEROSOLS IN THE AIR AROUND THE FACILITIES OF WASTE COLLECTION AND DISPOSAL

Exposure to bioaerosols at various stages of waste management system (collection, transfer and disposal) has been evaluated by recording of the bacterial and fungal concentrations in the air around these facilities. Regardless of the season, the total bacteria and total fungi were detected for all samples, whereas the fungal genera were not. The bioaerosol concentrations measured in the waste collection bins were significantly higher than those of the transfer station and landfill site. The mean microbial concentrations at wastes container bins and in-operation trench exceeded the Iran outdoor bioaerosol guidelines (850 CFU/m^3), thus suggesting the need for remedial action regarding microorganisms, in order to reduce the exposure at the wastes management system.

1. INTRODUCTION

Exposure to biological agents and dusts occurs in homes and occupational environments [1] and it is known to causes adverse health effects including infectious diseases [2], acute toxic effects, allergies and cancer [3]. Respiratory symptoms and lung function impairment are the most widely studied and probably among the most important bioaerosol-associated health effects [4]. New industrial activities have emerged in recent years in which exposures to bioaerosols can be abundant, e.g. waste recycling and composting industry [5], biotechnology industries producing highly purified enzymes and the detergent and food industries that make use of these enzymes [6]. There is limited information concerning the occupational exposure levels of airborne biohazard during wastes collection and disposal, but this exposure is associated with a range of adverse health effects [7]. Control of exposure to microbiological hazards in wastes collection and disposal is not easy. In wastes management systems, various types of

[1]School of Health, Shahroud University of Medical Sciences, Shahroud, Iran, corresponding author A. Roodbari, e-mail: roodbari@shmu.ac.ir

[2]School of Public Health, Tehran University of Medical Sciences, Tehran, Iran. e-mail: knadafi@tums.ac.ir

wastes are collected and they generate complex mixtures of dusts and biological agents with various health risks [8]. Although there has recently been a gradual increase in the scientific database regarding exposure to bioaerosols in the workplaces of several countries [9–11], significant data on the bioaerosol exposure in many unsurveyed occupational environments are still needed in order to properly link occupational bioaerosol exposure to health effects. Consequently, the present study evaluated exposure to bioaerosols at three wastes management facilities (wastes container bins, transfer station, and wastes landfill site) by measuring the bacterial and fungal concentrations in air. This study focuses on viable bacteria and fungi, which exist in an airborne state as single cells or clumps [12]. The aim of the study was to investigate bioaerosols in the air around the wastes collection and disposal system workers breathe in Shahroud (Iran).

2. EXPERIMENTAL

Sampling. The bacterial and fungal concentrations in the air around the wastes management facilities (wastes container bins, transfer station, and wastes landfill site) have been measured during the spring, summer and autumn of 2010. For each of the three type's facilities, 30 air samples were collected during the each season. The same facilities participated in the spring, summer and winter studies. Each season under study was subdivided into three periods (first, second and third month). The majority of bioaerosol samples were taken from the center of the facilities at breathing height (1.6 m) mainly between noon and 08:00 on Tuesdays. All bioaerosol samples were collected without controlling any outdoor environmental conditions.

Bioaerosol sample analysis. For viable bioaerosol sampling, single-stage Anderson samplers were employed. The samplers had 400 holes 0.25 mm in diameter, and they drew air at thea flow rate of 28.3 dm^3/min (corresponding to velocity of 24 m/s). The bioaerosol samplers were calibrated prior to and following the collection of each sample with a flow calibrator (DCL-H, Bios, Butler, NJ). The average of these two rates was then used as the sample flow rate for all volume calculations. No samples varied more than 10% from the initial flow rate during the study. During sampling, the temperature and relative humidity were recorded. Each bioaerosol sample was collected between 0.5 and 2 min on nutrient media (specific to either fungi or bacteria) in Petri dishes located on the impactor [12]. Dichloran glycerol 18 agars (DG-18) were applied for fungi and chloramphenicol was added to inhibit bacterial growth [13]. Trypticase soy agar (TSA) was used for bacteria and cycloheximide was added to inhibit fungal growth. The DG-18 and TSA plates were incubated at room temperature between 3 and 7 days and 2 and 5 days, respectively. The counts for the air sample plates were corrected for multiple impactions by using the positive whole conversion

method [14] and they were reported as colony forming units per cubic meter of air (CFU/m^3). The genera of certain cultures of fungi and bacteria were identified based upon their micro- and macromorphological characteristics, using standard taxonomic keys [15].

Statistical analyse. Statistical analyses were performed using the SPSS program (Version 16) on a personal computer. GM and geometric standard deviation (GSD) were used to characterize the log-normally distributed data and also computing the frequencies and the occurrence levels.

3. RESULTS AND DISCUSSION

3.1. OCCURRENCE LEVELS OF AIRBORNE BACTERIA AND FUNGI

Table 1 presents the occurrence levels of airborne bacteria and fungi identified in the air around the wastes management facilities for three seasons (spring (Sp), summer (Su) and autumn (Au)). Along with the total bacterial and total fungal counts, the current study also determined the levels of the four most prevalent fungal genera and bacterial species typically detected in many occupational as well as non-occupational environments [16, 17].

Table 1

Occurrence levels of the airborne bacteria and fungi identified in the air around the wastes management facilities

Bioaerosol		Wastes container bins			Transfer station			In-operation trench			Old landfill		
		Sp	Su	Au	Sp	Su	Au	Sp	Su	Au	Sp	Su	Au
Bacteria	total bacteria	100	100	100	100	100	100	100	100	100	100	100	100
	Staphylococcus	71	76	71	49	54	51	50	59	51	23	21	23
	Bacillus cereus	67	72	68	45	51	46	46	53	46	14	19	15
	Lactobacillus	17	23	18	13	17	14	15	20	16	5	7	5
Fungi	Total fungi	100	100	100	100	100	100	100	100	100	100	100	100
	Cladosporium	70	74	71	52	56	52	60	64	61	20	23	21
	Aspergillus	63	70	65	47	52	48	56	59	57	15	18	14
	Alternaria	15	21	17	11	14	11	12	16	12	5	8	5

Sp – spring, Su – summer, Au – autumn.

Regardless of the season, the total bacteria and total fungi were detected for all samples, whereas the fungal genera were not. For most of the fungal genera, the occurrence level was usually higher in the summer than in the other seasons. The occurrence levels for *Cladosporium* and *Aspergillus* were much higher than those of other

fungal genera, whereas the reverse was usually true for *Alternaria*. The occurrence levels of fungi were the highest in wastes container bins and the lowest in the old landfill. For most of the bacterial species, the occurrence level was usually higher in the summer than in the other seasons. The occurrence levels for *Staphylococcus* and *Bacillus cereus* were much higher when compared to those of other fungal genera, whereas the reverse was usually true for *Lactobacillus*. The occurrence levels of fungi and bacteria were the highest in wastes container bins and the lowest in old landfill.

3.2. BIOAEROSOL LEVELS AT THREE FACILITIES

The bioaerosol concentrations measured from the air around the wastes management facilities are summarized in Tables 2–5. The bioaerosol (both fungi and bacteria) concentrations measured in wastes container bins are significantly higher than those of

Table 2

Summary of the bioaerosol concentrations (bacteria and fungi) [CFU/m^3] measured in wastes collector bins according to season

Bioaerosol	Season	GM	GSD	Mean	Minimum	Maximum
Total bacteria	Spring	1340	2.1	1520	890	2125
	Summer	1358	1.8	1782	979	2358
	Autumn	1342	2.3	1542	856	2201
Staphylococcus	Spring	462	1.2	485	412	789
	Summer	489	1.3	509	459	852
	Autumn	472	1.2	471	421	742
Bacillus cereus	Spring	431	1.1	423	401	721
	Summer	468	1.2	459	431	743
	Autumn	428	1.1	413	407	716
Lactobacillus	Spring	36	1.2	26	21	46
	Summer	38	1.2	35	26	81
	Autumn	34	1.2	29	21	52
Total fungi	Spring	460	1.2	483	410	780
	Summer	482	1.3	512	455	846
	Autumn	469	1.2	473	418	738
Cladosporium	Spring	246	1.1	276	206	372
	Summer	277	1.2	206	251	323
	Autumn	264	1.1	264	213	329
Aspergillus	Spring	223	1.2	262	201	341
	Summer	252	1.3	289	223	303
	Autumn	237	1.1	241	201	310
Alternaria	Spring	56	1.2	52	42	91
	Summer	61	1.2	59	46	99
	Autumn	53	1.3	51	42	91

Table 3

Summary of the bioaerosol concentrations (bacteria and fungi) [CFU/m^3] measured in transfer station according to season

Bioaerosol	Season	GM	GSD	Mean	Minimum	Maximum
Total bacteria	Spring	603	1.8	700	400	957
	Summer	658	1.6	879	458	1189
	Autumn	684	1.6	784	423	1123
Staphylococcus	Spring	221	1.1	241	208	387
	Summer	235	1.2	254	221	416
	Autumn	246	1.2	236	201	367
Bacillus cereus	Spring	213	1.1	203	198	312
	Summer	231	1.2	224	208	326
	Autumn	211	1.1	204	199	315
Lactobacillus	Spring	18	1.1	14	12	28
	Summer	20	1.3	17	16	36
	Autumn	20	1.3	14	13	26
Total fungi	Spring	236	1.2	245	206	395
	Summer	247	1.1	259	238	429
	Autumn	237	1.2	246	208	399
Cladosporium	Spring	123	1.2	138	102	289
	Summer	138	1.2	158	137	301
	Autumn	124	1.1	141	110	291
Aspergillus	Spring	115	1.1	121	109	271
	Summer	126	1.2	143	121	278
	Autumn	114	1.1	123	107	262
Alternaria	Spring	28	1.1	26	21	46
	Summer	32	1.2	32	30	53
	Autumn	27	1.2	25	22	46

Table 4

Summary of the bioaerosol concentrations (bacteria and fungi) [CFU/m^3] measured in in-operation trench according to season

Bioaerosol	Season	GM	GSD	Mean	Minimum	Maximum
Total bacteria	Spring	938	1.3	1068	623	1490
	Summer	950	1.2	1248	689	1650
	Autumn	937	1.3	1087	628	1469
Staphylococcus	Spring	918	1.1	1047	605	1465
	Summer	926	1.3	1221	665	1632
	Autumn	912	1.3	1056	603	1459
Bacillus cereus	Spring	898	1.1	1018	582	1611
	Summer	903	1.3	1204	643	1608
	Autumn	896	1.1	1013	608	1453
Lactobacillus	Spring	30	1.3	20	17	38
	Summer	33	1.2	24	21	46
	Autumn	30	1.2	19	18	37

Summary of the bioaerosol concentrations (bacteria and fungi) [CFU/m^3] measured in in-operation trench according to season

Total fungi	Spring	343	1.3	339	287	541
	Summer	358	1.3	359	318	584
	Autumn	347	1.2	332	284	540
Cladosporium	Spring	201	1.3	214	161	321
	Summer	277	1.2	206	251	323
	Autumn	264	1.3	264	213	329
Aspergillus	Spring	123	1.2	162	101	341
	Summer	152	1.2	189	123	303
	Autumn	137	1.3	141	101	310
Alternaria	Spring	23	1.2	24	19	29
	Summer	27	1.3	28	22	32
	Autumn	23	1.1	24	18	28

Table 5

Summary of the bioaerosol concentrations (bacteria and fungi) [CFU/m^3] measured in old landfill according to season

Bioaerosol	Season	GM	GSD	Mean	Minimum	Maximum
Total bacteria	Spring	310	1.3	352	204	453
	Summer	326	1.2	423	232	524
	Autumn	308	1.2	342	202	451
Staphylococcus	Spring	211	1.1	232	181	332
	Summer	219	1.1	243	199	349
	Autumn	210	1.1	231	180	330
Bacillus cereus	Spring	101	1.1	102	99	201
	Summer	121	1.3	113	106	221
	Autumn	98	1.2	100	91	193
Lactobacillus	Spring	9	1.1	10	8	17
	Summer	12	1.1	12	10	19
	Autumn	9	1.2	10	7	16
Total fungi	Spring	185	1.1	182	142	201
	Summer	193	1.3	199	168	234
	Autumn	184	1.1	182	140	202
Cladosporium	Spring	85	1.1	86	62	99
	Summer	89	1.2	90	78	111
	Autumn	83	1.2	83	64	97
Aspergillus	Spring	77	1.1	77	59	89
	Summer	81	1.3	85	81	100
	Autumn	76	1.2	76	58	81
Alternaria	Spring	10	1.1	11	8	15
	Summer	12	1.1	12	10	17
	Autumn	10	1.2	10	7	16

transfer station and landfill site. The previous studies reported that the mean total bacterial or fungal values in outdoor health care facilities ranged from 10 to 1×10^3 CFU/m^3 but the mean total bacterial and fungal values in this study were 890-2125 and 1450–2890, respectively.

Moreover, the mean microbial concentrations in the all facilities exceeded the Iran outdoor bioaerosol guidelines (850 CFU/m^3). Consequently, the current findings suggest the need for remedial action in order to reduce exposure to bioaerosols at wastes management facilities. Study of Chu-Yun [1] over a landfill site in China showed that concentrations of bacteria and fungi in 69% and 97% of samples were more than 10^3 CFU/m^3, respectively and *Penicillium* and *Aspergillus* fungi were most abundant. Study of Taha et al. [18] showed that concentrations of fungi in the compost plant, were $19–28\times10^3$ CFU/m^3 and 100 m lower was $61–102\times10^3$ CFU/m^3.

4. CONCLUSIONS

The present study evaluated the exposure to bioaerosols at the three facilities (wastes collector bins transfer station in-operation trench), by measuring the bacterial and fungal concentrations in the air. The current findings suggest the need for remedial action regarding outdoor microorganisms in order to reduce the exposure to such microorganisms in the workplace at the surveyed facilities.

ACKNOWLEDGEMENTS

The authors wish to thank research affair of Shahroud University of Medical Sciences for their support.

REFERENCES

[1] HUANG C.Y., LEE C.C., LI F.C., M.A YP., SU H.J., *The seasonal distribution of bioaerosols in municipal landfill site*, Atmos. Environ., 2002, 36, 438.

[2] WANG Y.F., WANG C.H., HSU K.L., *Size and seasonal distribution of bioaerosols in commuting trains*, Atmos. Environ., 2010, 44, 4331.

[3] RAY M.R., ROYCHOUDHAURY S., MUKHERJEE G., ROY S., LAHIRI T., *Respiratory and general health impairments of workers employed in a municipal solid waste disposal at an open landfill in Delhi*, Int. J. Hyg. Envir. Health, 2005, 208, 255.

[4] VILAVERT L., NADAL M., INZA I., FIGUERAS M.J., DOMINGO J.L., *Baseline levels of bioaerosols and volatile organic compounds around a municipal waste incinerator prior to the construction of a mechanical-biological treatment plant*, Waste Manage., 2009, 29, 2454.

[5] JO W.K., KANG J.H., *Workplace exposure to bioaerosols in pet shops, pet clinics, and flower gardens*, Chemosphere, 2006, 65, 1755.

[6] MOLETTA M., DELGENES J.P., GODON J.J., *Differences in the aerosolization behavior of microorganisms as revealed through their transport by bioga*s, Sci. Total Environ., 2007, 379, 75.

[7] FANG Z.G., OUYANG Z.Y., HU L.F., WANG X.O., ZHENG H.A., LIN X.Q., *Culturable airborne fungi in outdoor environments in Beijing, China*, Sci. Total Environ., 2005, 350, 47.

[8] LIAO C.M., LUO W.C., *Use of temporal/seasonal- and size-dependent bioaerosol data to characterize the contribution of outdoor fungi to residential exposures*, Sci. Total Environ., 2005, 347, 787.
[9] FISCHER G., MÜLLER T., SCHWALBE R., OSTROWSKI R., DOTT W., *Exposure to airborne fungi, MVOC and mycotoxins in biowaste-handling facilities,* Int. J. Hyg. Envir. Health, 2000, 203, 97.
[10] ORSINI M., LAURENTI P., BONINTI F., ARZANI D., IANNI A., ROMANO-SPICA V., *A molecular typing approach for evaluating bioaerosol exposure in wastewater treatment plant workers*, Water Res., 2002, 36, 1375.
[11] PASTUSZKA J.S., KYAW T.P., LUIS D.O., WLAZŁO A., ULFIG K., *Bacterial and fungal aerosol in indoor environment in Upper Silesia, Poland*, Atmos. Environ., 2002, 34, 3833.
[12] ZAMORANO M., PAOLINI A., RAMOS A., RODRÍGUEZ M.L., *Adapting EVIAVE methodology as a planning and decision-making tool in Venezuela*, J. Hazard. Mater., 2009, 172, 993.
[13] WILLIAMS A.P., EDWARDS-JONES G., JONES D.L., *In-vessel bioreduction provides an effective storage and pre-treatment method for livestock carcasses prior to final disposal*, Biores. Technol., 2009, 100, 4032.
[14] O'GORMAN C.M., *Airborne Aspergillus fumigatus conidia: a risk factor for aspergillosis*, Fungal Bio. Rev., 2012, 25, 151.
[15] PEPPER I.L., BROOKS J.P., GERBA C.P., *Pathogens in Biosolids*, Adv. Agron., 2006, 90, 1.
[16] REN P., JANKUN T.M., BELANGER K., BRACKEN M.B., LEADERER B.P., *The relation between fungal propagules in indoor air and home characteristics*, Allergy, 2001, 56, 419.
[17] HONG J.B., CHUNG Y.H., CHANG Y.H., *Distribution of clinic airborne microorganisms in Seoul, Korea*, Korean J. Environ. Health, 2003, 29, 1.
[18] TAHA M.P.M., DREW G.H., LONGHURST P.J., SMITH R., POLLARD S.J.T., *Bioaerosols releases from compost facilities: evaluation passive and active source terms a green waste facility for improved risk assessments*, Atmos. Environ., 2006, 7, 1159.