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EXPOSURE OF INDIAN AGRICULTURAL WORKERS TO AIRBORNE MICROORGANISMS, DUST AND ENDOTOXIN DURING HANDLING OF VARIOUS PLANT PRODUCTS

Ewa Krysińska-Traczyk[1], Bhawanipant N. Pande[2], Czesława Skórska[1], Jolanta Sitkowska[1], Zofia Prażmo[1], Grażyna Cholewa[1], Jacek Dutkiewicz[1]

[1]Department of Occupational Biohazards, Institute of Agricultural Medicine, Lublin, Poland
[2]Department of Environmental Science, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, India

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Abstract: Microbiological air sampling with the use of personal sampler was performed in 14 small agricultural facilities located in Aurangabad (Southern India), including 5 farms (at harvesting and threshing), 6 godowns (small food storing and processing settings) and 3 grain or cotton mills. In 12 facilities, including harvesting on farms, godowns and mills, concentrations of airborne microorganisms were relatively low, ranging from 1.5×10^3 - 8.2×10^4 cfu/m^3. The striking rise in the concentrations of airborne microbes, by 2-4 orders of magnitude, was noted on 2 farms during threshing of maize (4.2×10^6 cfu/m^3) and pearl millet (1.1×10^7 cfu/m^3). This was due to release of large quantities of bacteria. During threshing of maize, the most common microorganisms were thermophilic actinomycetes (40% of the total count) and mesophilic actinomycetes of the genus *Streptomyces* (39%), while during threshing of pearl millet the most abundant were corynebacteria (68%) and Gram-negative bacteria (22%). Mesophilic bacteria formed 16.7-100% of the total airborne microflora and were prevalent in 11 out of 14 facilities. Thermophilic actinomycetes and fungi formed respectively 0-43.1% and 0-83.3% of the total count and were prevalent in 1 and 2 facilities. The concentrations of airborne dust and endotoxin recorded in the examined agricultural facilities, in most cases were very large and ranged from 2.5-257.5 mg/m^3, and from 0.0625-125.0 µg/m^3, respectively. In 10 out of 14 facilities, the concentrations of dust were of the order 10^1-10^2 mg/m^3, ranging from 25.0-257.5 mg/m^3. Similarly, in 7 out of 14 facilities the concentrations of endotoxin were of the order 10^1-10^2 µg/m^3, ranging from 31.25-125.0 µg/m^3. In conclusion, Indian agricultural workers could be exposed during handling of various plant materials to airborne biological hazards posing a risk of work-related respiratory disease. Of these, the most important are: bacterial endotoxin and allergenic species of bacteria and fungi. The greatest risk occurs at threshing of pearl millet and maize which requests an application of the appropriate prevention measures, such as wearing respirators by the workers and using modern threshing machines reducing the dustiness.

Address for correspondence: Dr Ewa Krysińska-Traczyk, Department of Occupational Biohazards, Institute of Agricultural Medicine, Jaczewskiego 2, 20-090 Lublin, Poland. E-mail: ekt@galen.imw.lublin.pl

Key words: agricultural workers, India, occupational exposure, organic dust, bioaerosols, bacteria, fungi, endotoxin.

INTRODUCTION

Work-related exposure to organic dusts and its effects, until recently have been studied mostly in the European and North American countries [9, 13, 25, 27, 28, 33] and much less in the countries of the subtropical and tropical zones. In India, this problem was explored mainly with regard to fungi [2, 5, 35, 36, 39], while relatively little is

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known about occupational exposure to bacteria and endotoxin associated with organic dust. In our earlier study [26], we found that settled plant dusts collected in godowns (small food storing and processing facilities) in the area of Aurangabad (Southern India) contain large quantities of bacteria and endotoxin.

The aim of the present study was to assess the degree of work-related exposure of Indian agricultural workers to airborne microorganisms, dust and endotoxin, based on measurements performed in small agricultural facilities (farms, godowns, mills) in the Aurangabad area.

MATERIALS AND METHODS

Examined facilities. Air sampling was performed in September/October 2000 in 14 small agricultural facilities located in the Aurangabad area, southern India, during handling of various plants and plant products. The full list of sampling sites (each corresponding to 1 facility), and activities performed during sampling, is presented in Table 1. Altogether, it comprises 5 farms (sites 1-5), 6 godowns (sites 7-9, 11, 12, 14) and 3 grain or cotton mills (sites 6, 10, 13) (Tab. 1).

Air sampling. The samples were taken by use of an AP-2A personal sampler (TWOMET, Zgierz, Poland), at the flow rate of 2 l/min. Glass fibre filters, with 1 μm pore size and 37 mm diameter, were used. At each site, 2 samples were collected, 1 for determination of the concentration and species composition of microorganisms, and the other for determination of endotoxin. The concentration of dust in the air was determined gravimetrically from the difference between weight of the filter measured before and after sampling. The concentration of airborne dust estimated for each site was a mean of 2 single determinations.

Microbiological examination of the air. The concentration and species composition of microorganisms in collected air samples were determined by dilution plating. The filters were extracted in 5 ml of sterile saline (0.85% NaCl) with 0.05% Tween 80, and after shaking, serial 10-fold dilutions were made. The 0.1 ml aliquots of each dilution were spread on duplicate sets of the following 5 media: blood agar for estimation of total mesophilic Gram-negative and Gram-positive bacteria, eosin methylene blue (EMB) agar (Difco, Detroit, MI, USA) for estimation of Gram-negative bacteria, half-strength tryptic soya agar (BioCorp, Warsaw, Poland) for estimation of thermophilic actinomycetes, malt agar (Difco, Detroit, MI, USA) for estimation of total fungi, and potato dextrose (PDA) agar (Merck, Darmstadt, Germany) for estimation of fungi belonging to *Fusarium* genus. The blood agar plates and EMB plates were subsequently incubated for 1 day at 37ºC, then 3 days at 22ºC, and finally 3 days at 4ºC. The malt agar plates were subsequently incubated for 4 days at 30ºC and 4 days at 22ºC [7]. The prolonged incubation at lower temperatures aimed to isolate as wide a spectrum of bacteria and fungi as possible. The tryptic soya agar plates were incubated for 5 days at 55ºC, and PDA plates were incubated for 7 days at 25ºC. The grown colonies were counted and differentiated and the data reported as cfu per 1 cubic metre of air (cfu/m^3). The total concentration of viable microorganisms in the air was obtained by the addition of the concentrations of total mesophilic bacteria (grown on blood agar medium), thermophilic actinomycetes and fungi. The percent composition of the total microflora of the air was then determined.

Bacterial isolates were identified with microscopic and biochemical methods, as recommended by Bergey's Manual [17, 37, 38] and Cowan & Steel [4]. Additionally, the selected isolates were identified with microtests: API Systems 20E and NE (bioMérieux, Marcy l'Etoile, France) and BIOLOG System (Biolog, Inc., Hayward, CA, USA). Fungi were identified with microscopic methods, according to Barron [1], Raper & Fennell [29], and Samson *et al.* [34].

Table 1. List of sampling sites and activities performed during sampling.

No.	Sampling site, activity
1	Farm, outdoor sickle harvesting of maize (*Zea mays*) crop by 4 workers.
2	Farm, outdoor sickle harvesting of sorghum (*Sorghum vulgare*) crop by 4 workers.
3	Farm, outdoor sickle harvesting of pearl millet (*Pennisetum typhoideum*) crop by 4 workers.
4	Farm, outdoor threshing of pearl millet (*Pennisetum typhoideum*) grain with a machine operated by 5 workers.
5	Farm, outdoor threshing of maize (*Zea mays*) grain with a machine operated by 6 workers.
6	Cotton mill, indoor carding and yarning of cotton (*Gossypium herbaceum*) fibre with machines operated by 35 workers.
7	Godown, indoor cleaning of Bengal gram (*Cicer arietinum*) grain with sieving machine operated by 3 workers.
8	Godown, indoor cleaning of sorghum (*Sorghum vulgare*) grain with sieving machine operated by 3 workers.
9	Godown, indoor cleaning of wheat (*Triticum vulgare*) grain with sieving machine operated by 3 workers.
10	Cotton mill, threshing of cotton (*Gossypium herbaceum*) fibre with a machine operated by 4 workers (for making mattresses).
11	Godown, indoor cleaning of red gram (*Cajanus cajan*) grain with sieving machine operated by 3 workers.
12	Godown, indoor cleaning of sorghum (*Sorghum vulgare*) grain with sieving machine operated by 3 workers.
13	Grain mill, indoor grinding of various kinds of grain for flour, with a machine operated by 2 workers.
14	Godown, indoor cleaning of rice (*Oryza sativa*) grain with sieving machine operated by 4 workers.

The concentration of bacterial endotoxin in the airborne dust was determined by the *Limulus* amebocyte lysate (LAL) gel clot test [22]. The filters were extracted for 1 hr in 10 ml of pyrogen-free water at room temperature, heated to 100ºC in a Koch apparatus for 15 min (for better dissolving of endotoxin and inactivation of interfering substances), and after cooling, serial dilutions were prepared. The 0.1 ml dilutions were mixed equally with the "Pyrotell" *Limulus* reagent (Associates of Cape Cod, Inc., Falmouth, MA, USA). The test was incubated for 1 hr in a water bath at 37ºC, using pyrogen-free water as a negative control and the standard lipopolysaccharide (endotoxin) of *Escherichia coli* 0113:H10 (Difco) as positive control. The formation of a stable clot was regarded as a positive result. The estimated concentration of endotoxin in dust (ng/mg) was multiplied per estimated concentration of dust in the air (mg/m^3) and the results were reported as micrograms of the equivalents of the *E. coli* 0113:H10 endotoxin per 1 m^3 of air. To convert to Endotoxin Units (EU), the value in nanograms was multiplied by 10.

RESULTS

The concentrations of total viable microorganisms in the air of the 16 Indian agricultural facilities examined showed a marked variability. In 12 facilities, including harvesting on farms, godowns and mills, concentrations of airborne microorganisms were relatively low, ranging from 1.5 × 10^3 - 8.2 × 10^4 cfu/m^3. The striking rise in the concentrations of airborne microbes, by 2-4 orders of magnitude, was noted on 2 farms during threshing of harvested grain in the field. During threshing of maize, the concentration of total microorganisms in the air was 4.2 × 10^6 cfu/m^3 and during threshing of pearl millet it was 1.1 × 10^7 cfu/m^3 (Tab. 2). The observed rise of airborne microbes during threshing was due to the release of large quantities of bacteria, at the total absence of fungi. During threshing of maize, the most common microorganisms were thermophilic actinomycetes (40%) and mesophilic actinomycetes of the genus *Streptomyces* (39%), while during threshing of pearl millet the most abundant were corynebacteria (68%) and Gram-negative bacteria (22%) (Fig. 1).

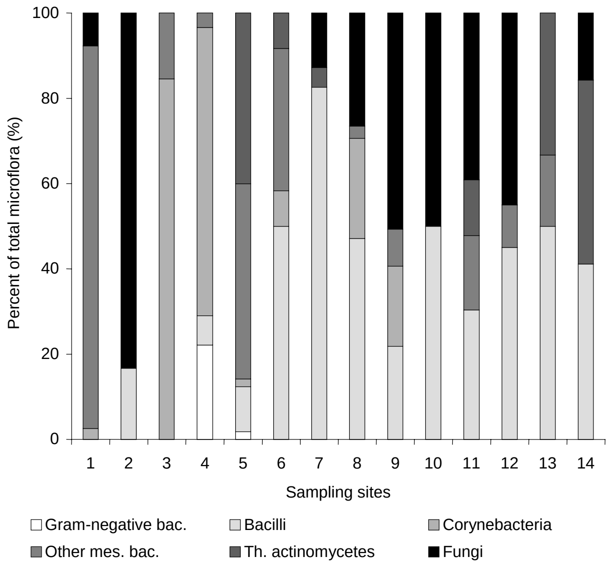

Figure 1. Composition of airborne microflora in Indian agricultural facilities: total count, including mesophilic bacteria, thermophilic actinomycetes and fungi. The "other mesophilic bacteria" comprise mesophilic actinomycetes (*Streptomyces* spp.) and cocci (*Staphylococcus* spp., *Micrococcus* spp.).

Altogether, mesophilic bacteria formed 16.7-100% of the total airborne microflora and were prevalent in 11 out

Table 2. Concentrations of viable microorganisms in the air of Indian agricultural facilities (cfu/m^3 × 10^3).

Sampling site	Total mesophilic bacteria (Blood agar)	Gram-negative bacteria (EMB agar)	Thermophilic actinomycetes (Tryptic soya agar)	Fungi (Malt agar)	*Fusarium* spp. (PDA agar)	Total microorganisms*
1	27.0	0	0	2.25	0	29.25
2	0.75	0	0	3.75	0.75	4.5
3	19.5	0	0	0	0	19.5
4	10,875.0	307.5	0	0	0	10,875.0
5	2,550.0	0.75	1,701.75	0	0	4,251.75
6	8.25	0	0.75	0	0	9.0
7	67.5	0	3.75	10.5	0	81.75
8	18.75	0	0	6.75	0	25.5
9	25.5	1.5	0	26.25	4.5	51.75
10	0.75	0	0	0.75	0	1.5
11	16.5	0	4.5	13.5	0	34.5
12	8.25	0	0	6.75	0	15.0
13	3.0	0	1.5	0	0	4.5
14	15.75	0	16.5	6.0	0	38.25
Median	17.6	0	0	3.0	0	27.4

*Sum of the concentrations of mesophilic bacteria, thermophilic actinomycetes and fungi.

of 14 facilities. Thermophilic actinomycetes and fungi formed respectively 0-43.1% and 0-83.3% of the total count and were prevalent in 1 and 2 facilities.

In most facilities, endospore-forming bacilli (*Bacillus* spp.) prevailed among mesophilic bacteria (Fig. 1). They were, less abundant however, in large quantities of bacteria recorded during threshing. Gram-negative bacteria were isolated in 3 facilities. Gram-negative flora was most abundant at threshing of pearl millet, consisting of *Enterobacter* spp. (51%) and *Flavimonas oryzihabitans* (49%). The other Gram-negative bacteria recovered from examined facilities (*Acinetobacter calcoaceticus*, *Pseudomonas putida*, *Xanthomonas maltophilia*) occurred in small numbers.

Corynebacteria distinctly prevailed during threshing of pearl millet. Among them, the dominant species were *Microbacterium laevaniformans* and *Tsukamurella inchonensis*, which formed respectively 70.4% and 27.6% of total isolates. In other facilities, corynebacteria occurred in much smaller quantities, and the most numerous species was *Curtobacterium pusillum*.

Actinomycetes occurred in large quantities, of the order 10^6 cfu/m^3, during threshing of maize. The mesophilic species belonged to the genus *Streptomyces*, while among thermophilic actinomycetes the prevalent species was *Saccharopolyspora rectivirgula* which formed 78.4% of total isolates. The remaining thermophilic isolates were: *Saccharomonospora viridis* (10.6%), *Thermomonospora fusca* (8.8%), and *Thermoactinomyces thalpophilus* (2.2%). In other facilities, thermophilic actinomycetes were less common, and consisted mostly of *Thermoactinomyces* species.

Fungi occurred in the air of the examined facilities in the concentrations of the order 10^3-10^4 cfu/m^3 and never attained the levels of bacteria. Dominant were *Aspergillus* strains which constituted 60.2% of total fungi. Among them, most common were species *Aspergillus proliferans* and *Aspergillus glaucus* which formed respectively 23.9% and 23.0% of total fungi. *Fusarium* species, which attack grain and produce trichothecene mycotoxins, occurred in the air of examined facilities only in small quantities.

Table 4. Concentrations of dust and bacterial endotoxin in the air of Indian agricultural facilities.

Sampling site	Concentration of dust (mg/m^3)	Concentration of endotoxin (μg/m^3)
1	2.5	0.0625
2	2.5	0.0625
3	7.5	0.625
4	55.0	31.25
5	92.5	31.25
6	2.5	0.0625
7	115.0	62.5
8	70.0	6.25
9	50.0	62.5
10	25.0	0.625
11	77.5	62.5
12	130.0	125.0
13	150.0	1.25
14	257.5	124.9
Median	62.5	18.75

In the air samples taken in the examined facilities, 24 species or genera of bacteria and 19 species or genera of fungi were identified, of these, 9 and 11 species or genera respectively were reported as having allergenic and/or immunotoxic properties [8, 12, 19, 20, 24, 34] (Tab. 3). These figures are certainly an underestimation, as a part of bacterial and fungal strains could be identified only to generic level.

The concentrations of airborne dust and endotoxin recorded in the examined agricultural facilities, in most cases were very large and ranged from 2.5-257.5 mg/m^3, and from 0.0625-125.0 μg/m^3, respectively (Tab. 4). In 10 out of 14 facilities, the concentrations of dust were of the order 10^1-10^2 mg/m^3, ranging from 25.0-257.5 mg/m^3. Similarly, in 7 out of 14 facilities the concentrations of endotoxin were of the order 10^1-10^2 μg/m^3, ranging from 31.25-125.0 μg/m^3.

Table 3. List of microbial species and genera identified in the samples of air from Indian agricultural facilities.

Gram-negative bacteria: ***Acinetobacter calcoaceticus****+ (4), ***Enterobacter* spp.**+ (4), *Flavimonas oryzihabitans* (4), *Pseudomonas putida* (9), *Xanthomonas maltophilia* (5).

Bacilli: *Bacillus* spp. (2, 4-14).

Corynebacteria: ***Brevibacterium linens**** (6), *Curtobacterium pusillum* (3, 8, 9), *Microbacterium laevaniformans* (4), *Rhodococcus coprophilus* (9), *Rhodococcus rhodochrous* (3), *Tsukamurella inchonensis* (4).

Other mesophilic bacteria: *Micrococcus* spp. (1, 3), *Staphylococcus caprae* (1), *Staphylococcus epidermidis* (1), *Staphylococcus xylosus* (9), *Staphylococcus* spp. (1, 3-6, 9, 11), ***Streptomyces albus**** (5, 6, 9, 12), *Streptomyces* spp. (5, 6, 8, 11).

Thermophilic actinomycetes: ***Saccharomonospora viridis**** (5), ***Saccharopolyspora rectivirgula**** (synonyms: ***Faenia rectivirgula***, ***Micropolyspora faeni***) (5, 6), ***Thermoactinomyces thalpophilus**** (5, 7, 11, 14), ***Thermoactinomyces vulgaris**** (6, 11, 13, 14), ***Thermomonospora fusca**** (5).

Fungi: *Absidia ramosa* (9), ***Aspergillus candidus**** (7, 10), ***Aspergillus fumigatus****+ (9), *Aspergillus glaucus* (7, 8, 11, 12, 14), ***Aspergillus niger****+ (9, 11, 12), ***Aspergillus ochraceus***+ (7), *Aspergillus proliferans* (8, 9), *Aspergillus pseudoglaucus* (7), *Aspergillus repens* (9), *Aspergillus wentii* (7), ***Candida* spp.*** (8), *Cladosporium lignicola* (1, 2), ***Fusarium sporotrichioides***+ (2), ***Fusarium semitectum***+ (9), ***Mucor mucedo**** (7-9, 12, 14), ***Mucor* spp.*** (7), ***Penicillium* spp.*** (8, 11, 12, 14), *Prophytroma tubularis* (9), ***Rhizopus nigricans****+ (7, 8, 14).

Sites of isolation are given in parentheses. The names of the species reported as having allergenic and/or immunotoxic properties (see text) are in bold and marked as follows: * allergenic species; + immunotoxic species.

DISCUSSION

The results of this study indicate that Indian agricultural workers are exposed during work to various biological hazards that could be a cause of respiratory disorders. Singh *et al.* [35] have found that 36-40% of agricultural industry workers in India have definite work-related respiratory symptoms. The occurrence of these symptoms was related to the presence of allergenic and toxin-producing fungi which were found in considerable amounts in the agricultural working environment by these and other Indian authors [2, 5, 35, 36, 39]. The results of the present study demonstrate that besides fungi, bacteria and bacterial endotoxin should also be considered as potential agents of occupational disease in agricultural workers in India, and probably also in other countries of tropical and subtropical zones.

As evidenced by the results of this study, bacterial endotoxin poses the greatest hazard to Indian agricultural workers exposed to organic dust. In 9 out of 14 examined facilities, airborne endotoxin occurred in large quantities of the order 10^0-10^2 µg/m^3 exceeding values supposed to cause decrease of lung function over work shift and ODTS symptoms [32]. In 11 out of 14 examined facilities the concentrations of airborne endotoxin exceeded the OEL values proposed by Clark [3] (0.1 µg/m^3), Rylander [31] (0.1-0.2 µg/m^3), Malmros *et al.* [23] (0.1 µg/m^3), and by Górny & Dutkiewicz [15] (0.2 µg/m^3), and in all facilities exceeded the OEL values proposed by Laitinen *et al.* [21] (0.025 µg/m^3), and by Dutch Expert Committee on Occupational Standards (DECOS) [6] (0.005 µg/m^3). The large exposure to airborne endotoxin was associated with large exposure to airborne dust. In 10 out of 14 facilities the concentrations of airborne dust were of the order 10^1-10^2 mg/m^3, and in 11 facilities they exceeded the Polish OEL value of 4 mg/m^3 [30] by 2-64 times. The large concentrations of airborne dust and endotoxin found in the Indian agricultural facilities were similar to those recorded in Poland during processing of grain, herbs and flax [10, 11, 18].

The concentrations of viable microorganisms in the air of 12 out of 14 examined Indian agricultural facilities were of the order 10^3-10^4 cfu/m^3, much less compared to most values reported from the European and North American agricultural settings [7, 8, 9, 13]. However, during grain threshing in 2 facilities, very large microbial concentrations of the order 10^6-10^7 cfu/m^3 were recorded, which exceeded values reported from various European agricultural settings [9, 10, 11, 14, 18, 21].

As, so far, there are no internationally recognised Occupational Exposure Limit (OEL) values for bioaerosols, the results obtained in the present work could be compared only to the proposals raised by particular authors. As regards total viable airborne microorganisms, the OEL values proposed by Malmros *et al.* (10×10^3 cfu/m^3) [23] was exceeded in 10 out of 14 examined facilities, while in 2 facilities was exceeded the OEL value proposed by Dutkiewicz & Jabłoński (100×10^3 cfu/m^3) [8]. In 2 facilities the OEL value for airborne Gram-negative bacteria proposed by Clark [3] and Malmros *et al.* [23] was exceeded (1×10^3 cfu/m^3), and in 1 facility the OEL value proposed by Dutkiewicz & Jabłoński [8] and Górny & Dutkiewicz [15] (20×10^3 cfu/m^3). The OEL value proposed by Dutkiewicz & Jabłoński [8] and Górny & Dutkiewicz [15] for airborne thermophilic actinomycetes (20×10^3 cfu/m^3) was exceeded in 1 facility, while nowhere was exceeded the OEL value proposed by these authors for airborne fungi (50×10^3 cfu/m^3).

Extremely large quantities of airborne microorganisms were recorded during threshing of pearl millet and maize, 100-10,000 times greater than during performing of other activities. This finding is in accordance with our earlier study of the settled agricultural dusts from India [26] in which we concluded that the particular risk for the workers is associated with handling of maize and pearl millet.

On average, mesophilic Gram-positive bacteria were the most abundant microorganisms in the air of the examined facilities. They comprised corynebacteria, mesophilic actinomycetes, bacilli and cocci.

Corynebacteria occurred in a huge quantity (7.4×10^6 cfu/m^3) during threshing of pearl millet. These bacteria are commonly associated with organic dusts [24], and were isolated in large quantities from the air of Polish agricultural facilities [7, 10, 11, 14, 18]. So far, little is known about the potentially pathogenic properties of corynebacteria associated with organic dusts. Cases of allergic alveolitis caused by *Arthrobacter globiformis* and *Brevibacterium linens* have been reported [24], and the involvement of peptidoglycan produced by these bacteria in causing organic dust toxic syndrome (ODTS) cannot be excluded. It is noteworthy that during threshing of pearl millet in India, the dominant species among corynebacteria were *Microbacterium laevaniformans* and *Tsukamurella inchonensis*, which, to the best of our knowledge, have been never isolated from the air of agricultural settings, neither in Poland nor in other European and North American countries. Because of the common occurrence of these species, future studies on their role in causing work-related respiratory disorders among agricultural workers in India are highly requested.

At threshing of maize, the main hazard was posed by actinomycetes. Mesophilic actinomycetes, belonging to genus *Streptomyces*, occurred in a large amount of 1.0×10^6 cfu/m^3. Among them, there commonly occurred the strains of the species *Streptomyces albus*, which has been identified as a cause of allergic alveolitis [16]. At the same site, a large quantity of thermophilic actinomycetes was noted (1.7×10^6 cfu/m^3), and the concentration of total actinomycetes (mesophilic and thermophilic) amounted to 2.7×10^6 cfu/m^3 (79% of total microorganisms). Among the thermophilic actinomycetes isolated at this site, the prevalent species was *Saccharopolyspora rectivirgula* (1.3×10^6 cfu/m^3), known as the most important cause of farmer's lung, a specific form of allergic alveolitis [19]. Allergic alveolitis may be also caused by other species of thermophilic actinomycetes found in the Indian agricultural facilities: *Saccharomonospora viridis*, *Thermomonospora fusca*, *Thermoactinomyces thalpophilus* and *Thermoactinomyces vulgaris* [19, 20].

The concentration of the airborne Gram-negative bacteria was greatest during threshing of pearl millet. More than half of the isolates were *Enterobacter* strains which are known producers of endotoxin [8].

The concentrations of fungi found in the present study in the air of the Indian agricultural facilities are similar to those reported by Chitnavis & Khilare [2] and by Zahid *et al.* [39] for the air of grain storage godowns located in southern India. Among fungi recovered from the air of the examined facilities, there distinctly dominated the species belonging to genus *Aspergillus* which constituted on the average over 60% of total isolates. They comprise potentially pathogenic species (*A. fumigatus*, *A. niger*, *A. candidus*, *A. ochraceus*) known for their allergenic and/or toxic properties [8, 12, 34]. These findings are in accordance with the results of Indian researchers who found in the air of godowns and other agricultural settings an abundant occurrence of the potentially pathogenic *Aspergillus* strains [2, 5, 35, 39].

CONCLUSION

Indian agricultural workers, during handling of various plant materials, could be exposed to airborne biological hazards posing a risk of work-related respiratory disease. Of these, the most important are: bacterial endotoxin and allergenic species of bacteria and fungi. The greatest risk occurs at threshing of pearl millet and maize which necessitates the application of appropriate prevention measures, such as wearing respirators by the workers and using modern threshing machines reducing dustiness.

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