Original Research

Indoor Disposal of Household Waste as a Source of Environmental Biohazard Exposure

Alina Buczyńska*, Marcin Cyprowski, Irena Szadkowska-Stańczyk

Department of Environmental Health Hazards, Nofer Institute of Occupational Medicine,
Teresy 8, 91-348 Łódź, Poland

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Abstract

In our study we evaluated the technical condition and microbiological contamination (bacteria, fungi, bacterial endotoxins) of indoor chute devices (lower waste chambers, waste disposal rooms) in multistoried residential buildings. Microbiological analysis was performed according to the standard procedures. LAL test was used for endotoxins assay. The most frequently reported problem (76% of respondents) connected with the operation of indoor waste chute devices was odor nuisance due to sanitary negligence and frequently clogged chute channels. The average concentration of airborne microorganisms amounted to 1.66×10^3 cfu/m^3 (fungi: 1.17×10^3 cfu/m^3; bacteria: 4.96×10^2 cfu/m^3). Fourteen genera/species of the leading microorganisms were determined in indoor chute devices. The mean concentration of endotoxins amounted to 1.81±2.61 ng/m^3. The effect of seasonal variability of endotoxins' levels was observed (summer: 3.33 ng/m^3, winter: 0.98 ng/m^3, $p<0.001$). The highest level of biocontaminants was found in the chute premises located on the lowest floors of the buildings ($p<0.05$). The indoor waste chute systems in multistoried buildings constitutes a source of microbiological contaminants. Because of the common sanitary and technical negligences connected with the use of waste chutes, it's important to implement plans for cleaning and proper maintenance of the indoor chute devices or to make decisions about their liquidation.

Keywords: household wastes, indoor disposal, microorganisms, endotoxins, environmental exposure

Introduction

Municipal wastes produced in households contain approx. 30% of organic matter, constituting a perfect substratum for the life and development of many microorganisms. Biohazards (viruses, bacteria, fungi and their decomposition products: bacterial endotoxins and (1→3)-β-D-glucans) released in the form of bioaerosols from the sites of temporary and final waste storage constitute health hazards for waste management workers [1-6], and also for the general population, e.g. due to the direct neighbourhood of landfill sites or long storage of organic wastes in household environments [7-9]. The most frequently described health effects of exposure (mainly occupational) to biohazards present in wastes comprise: irritation of conjunctiva and skin, influenza-like symptoms (cough, breathlessness, muscular pain, shivering, fever), ailments of the alimentary system, as well as allergies, infections, and inflammations of the respiratory system [10-13]. In view of the above data, we might acknowledge the system of the indoor disposal of municipal wastes commonly used in multistoried buildings, the so-called indoor wastes chutes, as a source of discomfort and potential biohazards for inhabitants.

Requirements related to chute devices mounted in residential houses in Poland are determined by the Polish standard PN-91/B-94340 [14]. The chute devices provide for gravitational discharge of household wastes from particular stories of the building. The basic elements of the chute

*e-mail: alina@imp.lodz.pl

device are: chute duct, upper chamber with appliances for cleaning and airing of the chute duct, lower chamber with containers for storage and discharge of wastes, and chute premises between the lower and upper chamber on respective stories of the building, where a tipper for wastes is mounted (Fig. 1). Improper use of the chute devices causes odor emissions arising from digestion processes of organic matter, development of biological agents in lingering wastes, and in layers of pollutants deposited on the chute's ducts, as well as proliferation and spreading of insects, especially German cockroaches. Airborne microbiological pollution in buildings and the presence of insects in residential environment may affect the inhabitants' health, but so far scientific reports on this problem have been lacking.

The results presented in this publication are aimed at evaluation of the technical condition and microbiological contamination of indoor chute devices in multistoried residential buildings.

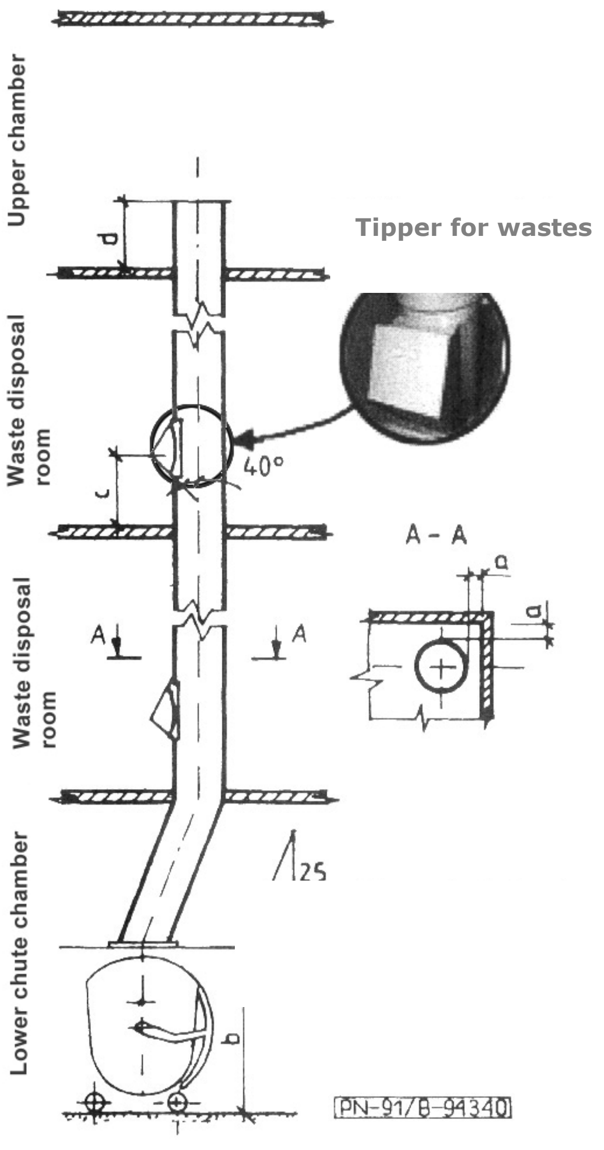

Fig. 1. Outline of the waste chute device in multistoried residential buildings in Poland [14].

Material and Methods

Our research was carried out in Łódź in 2006. The current data about the quantity of residential buildings, including multistoried buildings equipped with indoor chutes for household wastes, were obtained by mail from the Division of Buildings, Municipality of Łódź, and from 85 Housing Cooperatives.

Evaluation of the technical conditions of indoor chute devices was based on interviews carried out with representatives of companies dealing with cleaning, maintenance, and repair of chutes. Evaluation of the sanitary state of chutes, especially focused on biological agents (bacteria, fungi, endotoxins, as an index of contamination to Gram-negative bacteria), was carried out for five randomly selected multistoried buildings (3-staircase and 11-floor buildings) where chute devices were cleaned in a period not shorter than six months from the date of the planned research.

Period of Research, Measurement Points, and Number of Tests

Bacterial and fungal contamination was determined in air samples collected in one of the selected buildings (building 5: lower chute chamber, chute rooms – 1^{st} and 10^{th} floor) during the summer (June), in three repetition for each sampling point (n=9).

In view of the effects of seasonal variability and possible impact of waste lingering time in the main chute room on the level of microbiological contamination in the buildings, air sampling for endotoxin analysis was carried out twice a year (June, November) and twice a week (Monday, Friday). Air samples were collected once in lower chute chambers (n=20) and in chute rooms on two different stories of the buildings (1^{st} and 10^{th} floor) (n=40). Additionally, in direct neighborhood of the investigated buildings the outdoor air samples were collected (background level) (n=10).

Air Samples and Their Analysis

Air sampling for the presence of microorganisms was carried out using impactor FH5 (Klotz), directly on agar plates of 80 mm diameter, for 15 sec., maintaining the 100 l/min flow [15]. After incubation, microorganisms were identified according to standard procedures, using diagnostic media and biochemical tests (API, BioMerieux) and on the basis of microorganisms' morphological traits [16-19]. Isolated bacteria and fungi were characterized in view of their effects on human organisms [20, 21]. The microbial contamination was expressed as colony forming units (CFU) per cubic meter.

Air sampling for the presence of bacterial endotoxins was carried out by means of "pump – head with filter" kits placed at 150 cm height (average breathing zone for children and adults). Pumps of Casella type were functioning at the 2 l/min air flow for 8 hours. A filter made of glass microfibres - type GF/A (Whatman) of 25 mm diameter was installed in sampling heads (7-hole aerosol sampler).

Table 1. Inhabitants' complains and comments on chute premises in surveyed buildings.

Complains/Comments	Buildings											
	Total		1		2		3		4		5	
	N=188		N=35		N=37		N=44		N=34		N=38	
	n	%	n	%	n	%	n	%	n	%	n	%
Odor*	143	76.0	24	68.6	27	73.0	23	52.3	30	88.2	29	76.3
Dirty chute hole	74	39.4	9	25.7	14	37.8	14	31.8	7	20.6	10	26.3
Clogged chute duct	54	28.7	9	25.7	9	24.3	11	25.0	12	35.3	13	34.2
Chute hole damage	49	26.1	5	14.3	12	32.4	12	27.3	10	29.4	10	26.3
Cockroaches present	43	22.9	8	22.8	8	21.6	10	22.7	8	23.5	9	21.0

N – number of respondents in the building covered by the research; *statistical significance between the buildings, p=0.01.

Analysis of bacterial endotoxins was carried out using the LAL (*Limulus Amebocyte* Lysate) test in kinetic, chromogenic version Kinetic-QCL (Cambrex). The results were presented as ng/m^3.

Questionnaire Survey

Inhabitants' opinions on the sanitary and technical condition of indoor chute devices were obtained from the questionnaire survey. The questionnaire was supplied to all residential apartments (n=408) in the buildings included in the research. 188 questionnaires (46% of distributed questionnaires) were returned; they were completed by representatives of families residing in the apartments.

Statistical Analysis

Statistical analysis was performed using the STATISTICA program (StatSoft, version 7.0). Distribution of respondent complains in the surveyed buildings were compared using likelihood ratio test for logistics regression. Endotoxin levels were log-transformed; the results were reported as geometric means (GM). Endotoxin levels were evaluated using nonparametric U Mann-Whitney test. In all analyses the level of significance was set at a p value of 0.05.

Results

Technical State of Indoor Chute Devices in the Opinion of Maintenance Staff

In 2006 in Łódź 9,668 residential buildings were registered, of which 716 (7%) constituted multistoried buildings equipped with an indoor system of household waste disposal.

The technical condition of chute devices, in the opinion of technical teams dealing with their repairs and maintenance, may be defined as bad. The common technical defects within the chute devices include improper and imprecise assembly of chute channel pipes (lack of coaxiality of connected elements) and defectively made enclosures of the tippers, which hinders efficient disposal of wastes. The most serious and frequent damage to chutes includes cracks, chipping, or even breaking off of large fragments within the chute channels; cracking and tearing of tippers and their enclosures; damage to the mechanism fastening the tippers to chute channels; bending the tipper enclosure edges, which inhibits a tight closure of tippers; and cracking of chute channels at the place where the tippers are mounted. All constructional defects and faults in indoor chute devices cause accumulation of impurities, intensified digestion processes, and emission of odors and bioaerosols from chute channels and premises.

Attention should also be paid to the fact that 98% of buildings in Łódź have chute channels made of cement-asbestos pipes. Following the obligation to liquidate asbestos materials, the chute channels will have to be replaced.

Evaluation of Waste Chute Devices in the Opinion of Inhabitants of the Investigated Buildings

Inhabitants' opinions on the chutes' sanitary and technical conditions, collected through the questionnaire survey, are presented in Table 1. The obtained results indicate that the most frequently reported problem connected with operation of indoor waste chute devices was odor nuisance due to sanitary negligence and frequently clogged chute channels (from 52% to 88% of questionnaired flats representatives). About 40% of respondents noted dirty chute holes. At the same time, the inhabitants emphasized the presence of German cockroaches within residential premises (23% of respondents). Besides odor, the percentage distribution of inhabitant complaints were similar in each building.

Airborne Microorganisms in the Waste Chute Premises

The mean microbiological contamination of waste chute systems amounted to 1.66×10^3 cfu/m^3 (Table 2). The total number of airborne bacteria and airborne fungi in all measurement points did not exceed 3.5×10^3 cfu/m^3 value. The average concentration of fungi (11.7×10^2 cfu/m^3) was almost three times higher than bacteria (4.96×10^2 cfu/m^3).

Table 2. Concentration of airborne microorganisms present in waste chute premises and chambers in surveyed buildings.

Sampling point	Bacteria (× 10^2 CFU/m^3)			Fungi (× 10^2 CFU/m^3)		
	AM	SD	min-max	AM	SD	min-max
Lower chute chambers	3.55	1.62	2.21-5.35	6.59	1.83	4.99-8.58
Waste disposal rooms 1st floor	6.78*	4.82	1.02-13.9	19.5**	7.22	13.1-32.0
Waste disposal rooms 10th floor	3.86	2.78	0.79-8.49	6.40	3.31	2.60-11.5
Total	4.96	3.71	0.79-13.9	11.7	8.16	2.60-32.0

*p=0.01, **p<0.001, statistical significance between the sampling points.

The highest level of biocontaminants was found in the lowest chute premises (Table 2). The average concentration of bacteria was over twice higher (p=0.01), and fungi – three times higher (p<0.001) in waste disposal rooms located on the 1st floor compared with those located on the highest floor of the buildings (10th floor) and lower chute chambers.

Microorganism concentrations in waste disposal rooms were significantly higher in samples collected when the chute hole was open (bacteria – waste disposal rooms 1st and 10th floor: p<0.01, p=0.04; fungi – waste disposal rooms 10th floor: p=0.02) (Fig. 2).

Altogether, in all air samples 14 genera and species of the leading microorganisms were determined (Table 3). The qualitative analysis of bacteria points to the dominance of Gram-positive bacteria represented by species of *Bacillus*, *Micrococcus*, and *Staphylococcus*. The mycological analysis of air purity indicated a dominance of moulds (Table 3). Predominant among them are species of *Aspergillus* genus, including pathogenic *Aspergillus fumigates*, as well as moulds of *Penicillium* genus.

Endotoxins in the Air of Waste Chute Premises

The mean concentration of bacterial endotoxins determined in waste chute premises and lower chambers amounted to 1.81±2.61 (0.30-10.4) ng/m^3. Differentiation of average levels of endotoxins according to seasons, days of the week, and sampling sites is presented in Fig. 3. Significant differences in concentrations were found depending on season. The highest concentration of endotoxins occurred in summer and reached 3.33 ng/m^3. In winter the average concentration of endotoxins was almost three times lower – 0.98 ng/m^3 (p<0.001). A slight differentiation of endotoxin concentrations was indicated during the week, with a tendency of higher levels at the beginning of the week: Monday – 2.39 ng/m^3, Friday – 1.95 ng/m^3, however did not exhibit statistical significance traits (p>0.05). The average concentration of endotoxins in chute premises (2.17 ng/m^3) was twice higher than in lower chute chambers (1.33 ng/m^3) (p=0.04).

Analysis of endotoxin levels exhibited a significant differentiation between respective buildings only in summer (p=0.02). The highest concentration of endotoxins (7.22 ng/m^3) was determined in chute premises of building 5, where it was several times higher than in the case of the other buildings (Table 4).

The average concentration of bacterial endotoxins in summer and winter – background level, obtained for outdoor air samples collected in immediate vicinity of the buildings, amounted to 0.62 and 0.05 ng/m^3, respectively.

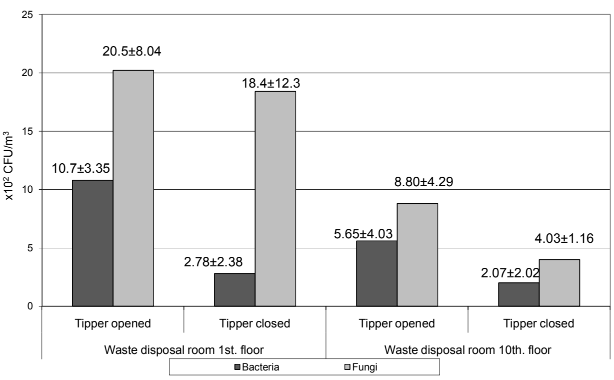

Fig. 2. Differences in microorganism concentrations in chute premises with open and closed chute holes at 1st and 10th floors.

Discussion

Polish and worldwide literature does not contain any research on biohazards connected with emission of biological agents from waste chute devices in multistoried buildings. On the other hand, the published results of environmental studies indicate negative effects of household wastes on the inhabitants' health. In a study concerning

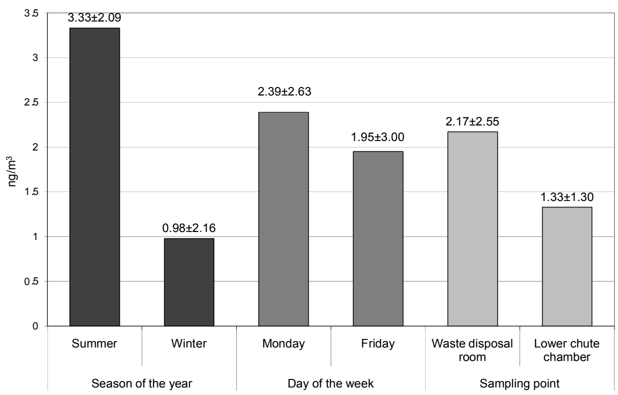

Fig. 3. Concentrations (geometric standard deviation) of bacterial endotoxins in waste chute premises according to seasons, days of the week, and sampling points.

Table 3. Concentrations of predominant airborne microorganisms present in waste chute premises and chambers in surveyed buildings.

Genera of bacteria	Number of colonies (cfu/m^3)	Genera of fungi	Number of colonies (cfu/m^3)
Total		Total	
Bacillus spp.	0.8-6.8 × 10^2	*Aspergillus fumigatus*	0.5-3.6 × 10^2
Staphylococcus lentus	0.8-2.4 × 10^2	*Aspergillus niger*	0.8-8.0 × 10^2
Micrococcus luteus	0.8-1.2 × 10^2	*Aspergillus* spp.	0.8-4.8 × 10^2
Staphylococcus xylosus	0.8-1.2 × 10^2	*Penicillium* spp.	0.8-4.8 × 10^2
Staphylococcus simulans	0.4 × 10^2	*Mucor* spp.	0.8-2.0 × 10^2
Staphylococcus haemolyticus	0.4 × 10^2	*Rhizopus* spp.	0.4-0.8 × 10^2
		Alternaria	0.4-1.2 × 10^2
		Rhodotoula spp.	0.4 × 10^2

Table 4. Concentrations of bacterial endotoxins in waste chute premises and lower chambers in respective buildings under the study and seasons.

Buildings	Endotoxins [ng/m^3]					
	Summer			Winter		
	GM	GSD	min-max	GM	GSD	min-max
No. 1	1.56	1.59	1.63-2.42	0.40	1.54	0.30-0.60
No. 2	3.36	1.54	2.22-6.93	1.23	1.60	0.98-2.15
No. 3	3.55	1.73	2.32-7.47	0.64	1.72	0.33-1.55
No. 4	1.09	1.61	0.95-2.34	-	-	-
No. 5	7.22*	1.36	6.50-10.4	2.09	1.77	1.62-3.11

*statistical significance between the buildings, p=0.02; (-) winter measurements are missing because of liquidation of the waste chute in the building.

household environmental contamination by microorganisms released from wastes, Wouters et al. [7] indicated a contribution of lingering organic wastes to increased levels of endotoxins, (1→3)-β-D-glucans and fungal extracellular polysaccharides (EPS) in the dust collected from floor surfaces in the kitchen and living rooms of 99 houses in Holland. The average geometric concentrations of endotoxins, (1→3)-β-D-glucans and EPS in the case of houses where segregated organic wastes were kept for a week and longer amounted to, for living rooms, respectively: 7,765 EU/g of dust, 1,010 μg/g dust, and 15,045 EPS units/g of dust, and for the kitchen 19,169 EU/g dust, 614 μg/g dust, and 5,928 EPS units/g of dust, and were over 3, 4, and 7 times higher than in houses where there were only inorganic wastes.

Herr et al. [8], in a study (in form of a medical interview) carried out among 384 persons residing in Germany in an area without industrial sources of contaminating atmospheric air with bioaerosols, evaluated the health effects connected with accumulation of organic wastes inside residential premises. In the group of people keeping organic wastes at home for more than 2 days, an increased risk of skin problems was found, such as: skin irritation (OR=3.58 [95% CI 1.61, 7.96]), skin itching (OR=2.77 [95% CI 1.33, 5.75]), and allergy (OR=2.74 [95% CI 1.28, 5.58]), as compared to a group of people who empty the wastes bin more often.

Mommers et al. investigated the impact of household environment on children's health and found that the duration of keeping the household wastes in flats was considered to be one of the risk factors that may adversely affect the functioning of the inhabitants' respiratory systems [9]. The obtained results indicated an increased risk of the occurrence of asthmatic symptoms and persistent cough in children, with decreased frequency of emptying the waste bins; but this correlation was not statistically significant.

Assuming the reference value for bacteria and fungi in residential environment as 5×10^3 cfu/m^3 [22], the microorganism concentrations determined in waste chute premises on the lowest stories of buildings reached that value, whereas in the case of the other samples they were by one order of magnitude lower. The highest levels of bacteria and fungi determined in the lowest chute premises may be associated with the immediate neighborhood of the household wastes accumulation site, i.e. the lower chute chamber with waste bins.

In all collected samples the concentration of fungi was over twice higher than the concentration of bacteria. The fungi dominance in the total amount of the determined microorganisms may be associated with intensive ventilation of the chute duct (at least 200 m^3/h), causing fast decaying of those microorganisms which are non-resistant to drying. The qualitative identification of microorganisms demonstrated (apart from typical environmental microorganisms, e.g. *Bacillus* sp., *Micrococcus* sp.) the presence of microorganisms which in people with deficient immunity may induce infections (*S. haemolyticus*, *S. simulans*). Instead, the mycological analysis of the collected samples demonstrated the presence of moulds, which may induce allergies and respiratory system diseases of immunotoxic type, i.e. aspergillosis.

In the case of bacterial endotoxins, in Poland the Expert Group on Biological Agents at the Interdepartmental Commission for Maximum Admissible Concentrations and Intensities for Agents Harmful to Health in the Working Environment proposed threshold limit values for endotoxins at residential rooms and non-industrial workplaces at the level of 5 ng/m^3 [22]. The obtained results in particular samples from building Nos. 2 and 3, and all samples from building No. 5, exceeded this value. The higher levels of endotoxins can be associated with increased levels of specific proinflammatory markers, and can be responsible for changes in pulmonary function, like a decline of the FEV_1 parameter [23].

Conclusions

The indoor waste chute devices in multistoried buildings constitute a source of microbiological contaminants.

Due to a significant share of buildings equipped with indoor waste chutes in the total number of residential buildings in Poland, and also due to the common sanitary and technical negligence connected with the use of waste chutes, it has become necessary to introduce and implement the plans of cleaning and proper maintenance of the indoor chute devices or to make a decision about their liquidation.

Acknowledgements

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