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Selected Heavy Metals in Settled Dust from Apartments Located in Lublin, Poland

Sławomira M. Dumała, Marzenna R. Dudzińska
Lublin University of Technology

1. Introduction

Nowadays people spend almost 90% of their time indoors, where the air creates a unique microclimate, with a composition different from the outdoor air and increased level of pollutants [15,21]. Indoor air pollutants may be found in the form of gas molecules, aerosols and suspended particles. Particulate matter is one of major interests of researchers and analysts, however, so far measurements were conducted mainly on the basis of particle size. Less attention was paid to the chemical composition of particles. Only information about SVOC sorbed on particles or alkali metals in ambient aerosols have been published [5,10,20,25,26,28].

Human activities increase concentrations of different elements and compounds in the atmosphere [9,23], for example heavy metals (Ba, Cu, Pb, Cr, Cd, Zn, Fe, Sn) [27], so as a result of atmospheric deposition one gram of dust may contain 700 million particles of different components including heavy metals. Heavy metals can impair important biochemical processes posing a threat to plant growth and animal life [13,17,22,29]. The exposure of these elements may have various health consequences depending on the exposure time.

However research on the heavy metals levels in the environment was focused on soil, sludge, food or roadside dust [7,19,24]. There is a limited number of data about heavy metals concentration in indoor dust and lack of information about heavy metals levels in relation to particle size distribution.

House dust is a highly heterogeneous mixture of aerosol particles settled on the surfaces. It consists of mineral and biological material, therefore it may contains organic and inorganic carbon, alkaline elements, heavy metals and complicated substances, including persistent organic pollutants.

Its precise composition in any particular building, or even room, will depend on a large number of factors including the location and construction of the building, the use of the room, types of decorating and furnishing materials used, heating and ventilation systems, how well and often the area is cleaned and even the time of year [8,10].

Health hazards of dust, which stem purely from its physical nature, especially from the presence of very small particle sizes, have been well recognized and documented for many years. However, the significance of dusts as accumulation of chemicals in a house, a potential source of chemical exposure, require further examination. Regular disposal of house dusts collected in vacuum cleaners undoubtedly act also as a potential source of more pervasive contamination, as in the case of outdoor dusts flow (especially roadside dusts) to sewers and storm-drains, which can lead to substantial secondary inputs to rivers [11].

The objective of this study is to assess the level of Sn, Pb, Cr, Zn, Cd (tin, lead, chromium, zinc, cadmium) in house dusts. Those heavy metals have high toxicity, which during life accumulate in the human body. Over the past decades, there has been increasing concern about exposure of people, especially of vulnerable groups such as children [17]. The reason is their behavior increasing indirect ingestion by way of hand-to-mouth activities, touching and mouthing of various dust-contaminated objects. Moreover, lower body-weight of children would result ingestion of greater amounts of dust compared to adults [6]. Moreover, children are less tolerant to most of the contaminates [1].

2. Material and Methods

The settled dust collected during the heating season in 5 apartments in Lublin (Fig. 1), Poland, was the object of the research. These apartments are located in the city center, along major thoroughfares as well as near to industrial area. The apartments are different in terms of the age of construction and indoor equipment (Table 1).

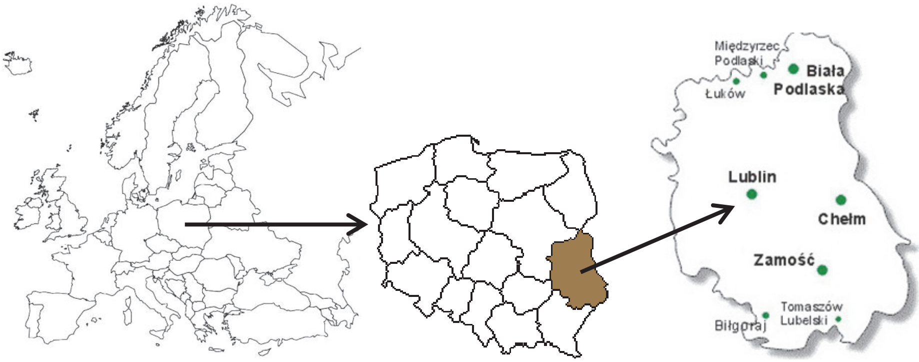

Fig. 1. Map showing the location of Lublin
Rys. 1. Mapa obrazująca lokalizację Lublina

Table 1. Description of the apartments
Tabela 1. Opis mieszkań

Code	Description of the apartment	Area [m^2]	Ventilation	Number of persons	Animals
A1	three-room apartment on the 4th floor; block of flat built of concrete slabs in the city center built in 80's; furnished with a leather sofa	60	natural	4	no animals
A2	two-room apartment on the 2nd floor, block of flat built in 70's	50	natural	2	cat
A3	apartment on the 2nd floor of a pre-war building	59	natural	3	no animals
A4	two-storey detached house built in 70's, near the industrial site (new windows)	150	natural	4 (one smoking person)	cat
A5	one-room apartment located on the 1st floor in block built in 80's	25	natural	2	no animals

In the research, the presence of heavy metals like tin, lead, chromium, zinc and cadmium was analyzed. The dust samples used in the study were taken from vacuum bags used in those particular apartments. Vacuum cleaners were with HEPA filters. In each apartment were carpets. The owners were asked to vacuuming at least once a week. The resulting material was sieved into different ranges of particle size (< 20, 20–25, 25–50, 50–100, 100–125 microns) using vibratory (GmbH &

Co.KG. Han) and pneumatic (HOKOSAWA ALPINE AG 200 LS) sieve shakers. The first process that dust samples were subjected to is the process of mineralization. This process was performed with the use of microwave digestion system Multiwave 3000 Microwave Anton Paar Company. In each range of particle size approximately 0.3 g of dust were measured and then introduced to a reaction flask. Then, 6 cm^3 of 65% HNO_3, 1 cm^3 of 30% HCl, 0.5 cm^3 49% HF and 1 cm^3 of 30% H_2O_2 were added to the dust samples. The process was conducted at the temperature of 160°C and a pressure of about $2x10^6$ Pa. After 55 minutes, 3 cm^3 of H_3BO_3 were added to the samples and mineralization process was continued in microwave mineralizer for 50 minutes. After mineralization, the samples were analyzed with the use of chemical technique ICP-OES 3000 conducted on sequential spectrometer ISA JobinYvon– JY 238 ULTRACE.

3. Results and discussion

The average concentrations of Sn, Pb, Cr, Zn, Cd in the indoor dust samples are summarized in Table 1. For all investigated metals the smallest range of particle size (<20 μm) achieved the highest average concentration. The concentrations of heavy metals in indoor dust from homes ranged from 3.5 to 27.26 mg/kg dust for Sn, from 17.21 to 113.40 mg/kg dust for Pb, from 30.76 to 172.82 mg/kg dust for Cr, from 198.30 to 1782.93 mg/kg dust for Zn, from 0.52 to 13.41 mg/kg dust for Cd. Sn, Pb, Cd obtained maximum concentration value for range of particle size lower than 20 μm, while Cr and Zn for 125–100 μm. When it comes to the minimum value, Sn, Cr, Zn, Cd reached it for range of 125–100 μm and Pb for 50–25 μm.

Figure 2 shows the measured concentration of Sn in different ranges of particle size. The highest concentration was achieved in apartment A4, while the lowest in A5.

When it comes to Pb, in the past it was a universal pollutant in an urban environment due to automobile emission [4]. Despite the gradual shift from leaded to unleaded petrol used as fuel for automobile, it still remains a major pollutant in some urban areas. Currently, additional research should be conducted to establish the source of this metal. The highest concentration of Pb were observed in apartments A1 and A4

(Fig. 3). In the case of the apartments A1 and A2, there was an upward trend with decreasing particle size distribution of the settled dust.

It is believed that car components, tires abrasion, lubricants, corrosion of cars, engine wear, thrust bearing, brushing, bearing metals and brake dust constitute the source of Cr in dust [2–4]. The highest concentration of Cr (Fig. 4) was noted in the apartment A1, which is located in the central part of the city. This component may have got into the apartment probably through an opened window or gravity ventilation system. Additional research should be conducted to establish the source of this element. The apartments A2, A3 and A5 reached the maximum concentration value for range lower than 20 µm.

In the case of Sn and Pb, the apartments with the highest number of residents (A1 and A4) obtained higher concentrations of those heavy metals. While recognizing the fact that the movement of occupant's in and out from building also contributed the heavy metals concentration in the building, its contribution was less obvious from the contribution from ambient sources [15]. Further studies are planned to analyze the sources of these metals.

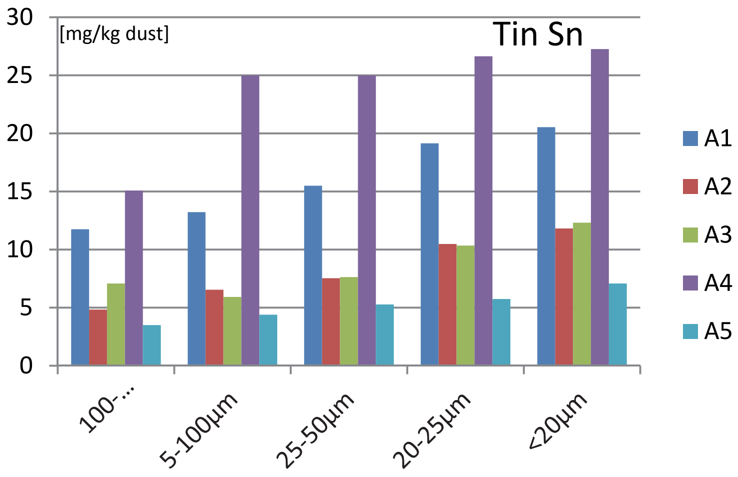

Fig. 2. Concentration of tin with respect to particle size range
Rys. 2. Stężenie cyny w zależności od zakresu wielkości cząstek

Table 2. Descriptive statistics of indoor dust heavy metal concentration
Tabela 2. Zestawienie stężenia metali ciężkich w kurzu domowym

		125–100 µm	100–50 µm	50–25 µm	25–20 µm	<20 µm
Sn	Min. [mg/kg dust]	3.50	4.39	5.27	5.74	7.08
	Max. [mg/kg dust]	15.08	24.99	24.98	26.64	27.26
	Average [mg/kg dust]	8.45	11.01	12.18	14.47	15.80
	Median	7.07	6.54	7.63	10.48	12.31
	Standard deviation	4.34	7.62	7.28	7.47	7.18
Pb	Min. [mg/kg dust]	18.50	20.51	17.21	21.35	29.97
	Max. [mg/kg dust]	80.51	100.79	96.28	93.69	113.40
	Average [mg/kg dust]	40.14	43.43	47.55	56.93	68.43
	Median	39.55	29.22	36.21	50.74	65.38
	Standard deviation	21.95	30.11	29.65	30.54	33.19
Cr	Min. [mg/kg dust]	30.76	32.27	42.44	47.40	57.27
	Max. [mg/kg dust]	172.82	114.17	92.93	80.21	133.40
	Average [mg/kg dust]	65.08	67.67	61.49	69.08	84.40
	Median	34.79	59.42	57.12	70.27	74.33
	Standard deviation	54.38	27.00	17.72	11.62	27.53
Zn	Min. [mg/kg dust]	198.30	296.72	434.68	425.09	502.41
	Max. [mg/kg dust]	1782.93	1518.13	1137.00	1239.09	1380.40
	Average [mg/kg dust]	721.71	676.30	621.22	694.12	819.12
	Median	588.88	522.41	482.87	574.80	689.64
	Standard deviation	555.04	430.63	264.62	289.96	300.17
Cd	Min. [mg/kg dust]	0.52	0.59	0.53	0.73	0.88
	Max. [mg/kg dust]	7.38	9.05	9.67	12.30	13.41
	Average [mg/kg dust]	2.59	2.81	3.29	4.23	5.10
	Median	1.25	1.40	2.03	3.14	4.17
	Standard deviation	2.59	3.15	3.32	4.17	4.47

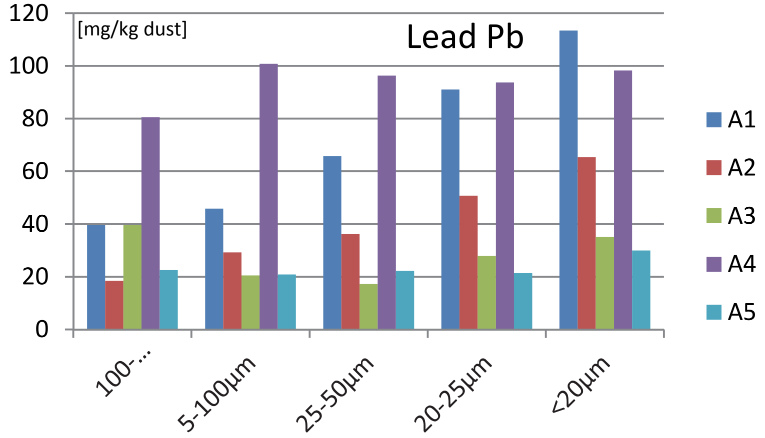

Fig. 3. Concentration of lead with respect to particle size range
Rys. 3. Stężenie ołowiu w zależności od zakresu wielkości cząstek

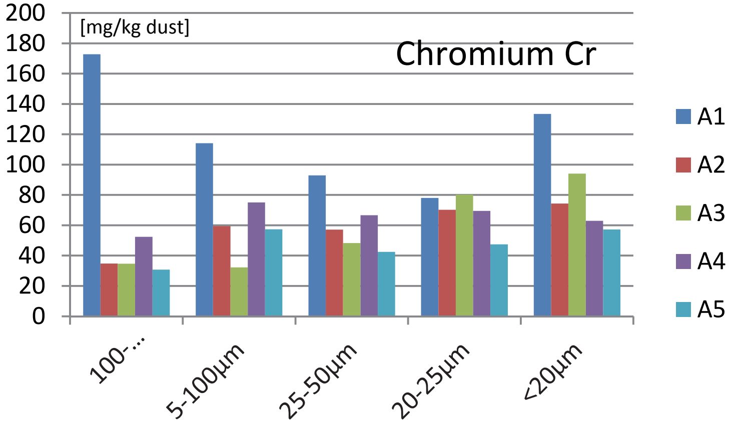

Fig. 4. Concentration of chromium with respect to particle size range
Rys. 4. Stężenie chromu w zależności od zakresu wielkości cząstek

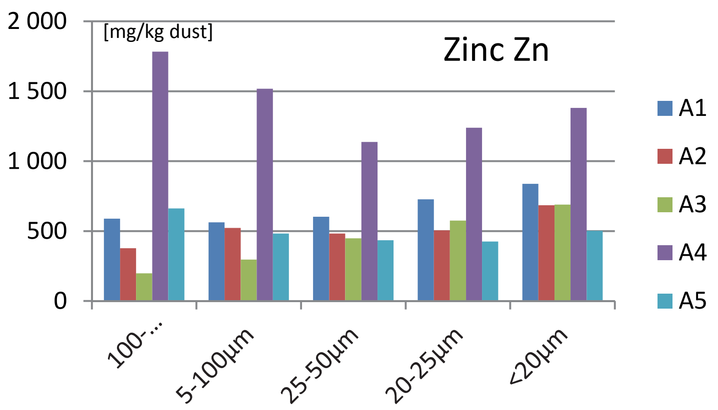

Fig. 5. Concentration of zinc with respect to particle size range
Rys. 5. Stężenie cynku w zależności od zakresu wielkości cząstek

Zinc is the fourth most common metal in use, as zinc oxide is widely used as a white pigment in paints. Zinc chloride is often added to lumber as a fire retardant and can be used as a wood preservative. Also zinc could be used as a vulcanization agent in tires. Moreover rubber carpets were identified as a significant source of zinc [13]. Figure 5 shows the concentration of Zn in different ranges of particle size. The highest concentration was achieved in apartment A4, while the lowest in A3. Probably the results were caused by the location of the apartments and varieties of furniture.

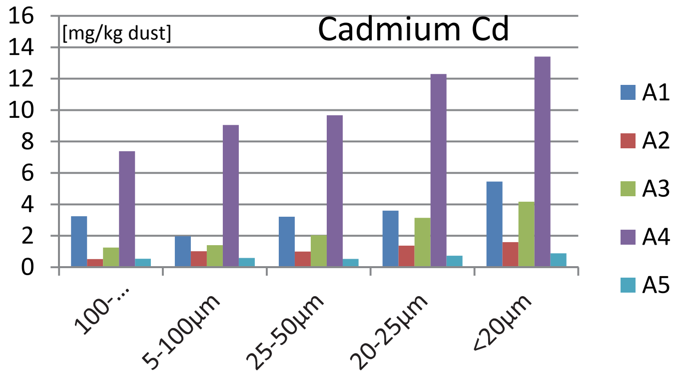

Fig. 6. Concentration of cadmium in different ranges of particle size
Rys. 6. Stężenie kadmu dla różnych zakresów wielkości cząstek

In the case of Cd ambient is not only likely source of cadmium in indoor air. Indoor sources, such a smoking and the agents used to color carpets and furniture, could result in increased cadmium in house dust. Figure 6 shows the concentration of Cd in different ranges of particle size. The highest concentration was achieved in apartment A4, while the lowest in A5. Similar like in the case of Zn results could be caused by the location of the apartments and varieties of furniture. Further studies are planned to analyze the sources of these metals.

4. Summary

Distribution of Sn average concentration in samples was characterized by an upward trend with decreasing particle size distribution of the settled dust.

The concentration of chromium in the tested material is higher in smaller ranges of particle size (except for the apartment A1).

Results reveal that the average concentration of all investigated metals in the dust samples was found in order Zn > Cr > Pb > Sn > Cd.

Monitoring plan is necessary to evaluate the evolution of metal concentration in dust in order to develop the proper measures for reducing the risk of inhalation.

Further studies are planned to analyze a larger number of apartments and sources of heavy metals in indoor dust.

Acknowledgement

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Wybrane metale ciężkie w wysedymentowanym kurzu domowym z mieszkań zlokalizowanych w Lublinie, Polska

Streszczenie

Kurz domowy nie jest jednorodną substancją pod względem fizycznym czy chemicznym, ale stanowi bardzo niejednorodną mieszaninę cząstek organicznych, nieorganicznych i substancji chemicznych. Jego skład w budynku, czy nawet w pokoju będzie zależeć od wielu czynników, między innymi od lokalizacji obiektu, jego konstrukcji, rodzaju wykorzystania, umeblowania, materiałów użytych do wykończenia lub dekoracji, systemu ogrzewania i wentylacji, jak również od częstotliwości sprzątania czy pory roku.

Celem tych badań jest określenie stężenia Sn, Pb, Cr, Zn, Cd (cyny, ołowiu, chromu, cynku, kadmu) w kurzu domowym. Wybrane do badań metale ciężkie mają wysokość toksyczność. Długotrwała ekspozycja powoduje ich kumulację w organizmie. W ciągu ostatnich dziesięcioleci wzrosło zainteresowanie związane z narażeniem ludzi na substancje zawarte w kurzu domowym, zwłaszcza wśród grup szczególnie narażonych takich jak dzieci. Powodem jest ich zachowanie i odruchy związane z poznawaniem otoczenia (dotykanie przedmiotów, branie ich do ust). Dlatego w stosunku do swojej niskiej wagi ciała dzieci spożywają większe ilości pyłów niż osoby dorosłe. Ponadto gorzej tolerują większość zanieczyszczeń.

Przedmiotem badań był wysedymentowany kurz domowy zbierany w sezonie grzewczym z 5 mieszkań zlokalizowanych w Lublinie. Próbki pobierano z worków odkurzaczy. Uzyskany materiał przesiewano do różnych zakresów wielkości cząstek (< 20, 20–25, 25–50, 50–100, 100–125 mikrometrów) za pomocą przesiewacza wibracyjnego i pneumatycznego.

W przypadku wszystkich badanych metali najmniejszy zakres wielkości cząstek (< 20 mikrometrów) osiągnął największe średnie stężenia. Stężenie metali ciężkich w kurzu domowym wahało się od 3,5 do 27,26 mg/kg kurzu dla Sn, od 17,21 do 113,40 mg/kg kurzu dla Pb, od 30,76 do 172,82 mg/kg kurzu na Cr, od 198,30 do 1782,93 mg/kg kurzu dla Zn, od 0,52 do 13,41 mg/kg kurzu dla Cd. Sn, Pb, Cd uzyskało maksymalną wartość stężenia dla zakresu wielkości cząstek poniżej 20 mikrometrów, a Cr i Zn dla 125-100 mikrometrów. Jeśli chodzi o wartości minimalne Sn, Cr, Zn, Cd osiągnęły ją dla zakresu 125–100 mikrometrów a Pb dla 50–25 mikrometrów. Wyniki pokazują, że średnie stężenie wszystkich badanych metali w kurzu wystąpiło w kolejności Zn > Cr > Pb > Sn > Cd.

Koniecznym staje się opracowanie sposobu monitorowania i oceny zmian stężenia metali w kurzu w celu opracowania odpowiednich środków zmniejszających ryzyko narażenia.

Słowa kluczowe:
stężenie metali ciężkich, cyna, ołów, chrom, cynk, kadm, kurz domowy

Keywords:
heavy metal contamination, tin, lead, chromium, zinc, cadmium, house dust