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Heavy metals content in breast milk of mothers living in industrial region

Zawartość metali ciężkich w mleku kobiet mieszkających na terenach uprzemysłowionych

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(a) *concept*
(b) *collection of material for research*
(c) *chemical analysis*
(d) *statistics*
(e) *working on text and references*
(f) *interpretation*

ABSTRACT

Introduction and Aim. Breast milk is the first nourishment in the infancy period containing environmentally present chemical compounds. Literature data on the presence of heavy metals in mothers' milk is insufficient. The study is to determine the influence of environmental factors on the content of heavy metals in breast milk. **Material and Methods**. This paper presents results of an investigation on the occurrence of heavy metals in breast milk. Absorption spectrometry technique using VARIAN Techtron Instrument type 5DA determined the content of Cu, Cd, Pb, Zn, Ni, Mn, Fe. The mothers were 16 to 40 years old and lived at least 5 years in the industrial region (Upper Silesia and Częstochowa, Cieszyn – Poland). **Results**. The co-occurrence of metals in the milk and the change of heavy metals concentration depends on the lactation time. Smoking and air pollution are important factors which influence the content of heavy metals in breast milk. **Conclusions**. Breast milk for infants is an important source of nourishment containing heavy metals.

Keywords: breast milk, heavy metals, industrial area, tobacco smoke

STRESZCZENIE

Wstęp i cel. Mleko kobiety jest pierwszym pokarmem zawierającym związki chemiczne obecne również w jej środowisku. Celem prowadzonych badań było określenie wpływu czynników środowiskowych na zawartość metali ciężkich w mleku kobiet. **Materiał i metody**. W pracy przedstawiono wyniki badań nad występowaniem metali w mleku kobiecym. Zawartości Cu, Cd, Pb, Zn, Ni, Mn, Fe oznaczano metodą AAS. Użyto aparatu VARIAN-5A. Badaniom poddano kobiety w wieku 16–40 lat, które mieszkały co najmniej 5 lat na Górnym Śląsku, w Cieszynie i Częstochowie. **Wyniki**. Współwystępowanie metali w mleku zależało od okresu laktacji. Czynnikiem wpływającym na zawartość metali w mleku były: stopień zanieczyszczenia przyziemnej warstwy powietrza oraz dym tytoniowy jako produkt oddziałujący na organizm karmiącej kobiety inhalowany zarówno podczas czynnego, jak i biernego palenia tytoniu. **Wnioski**. Mleko kobiece może być źródłem znaczącej ilości metali ciężkich.

Słowa kluczowe: mleko kobiece, metale ciężkie, obszar przemysłowy, nałóg palenia

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INTRODUCTION AND AIM

Breast milk is the first nourishment in the infancy period possibly containing many elements and chemical compounds which occur in the environment. Literature data on the presence of heavy metals in breast milk are insufficient.

The content of trace elements in milk depends on geographical, social and economic conditions of breast feeding mothers and the quality of food consumed. The papers published by Anderson [1], Davison [2] and Rocckens [3] point to the importance of the problem. They claim that during seven months of infant breast feeding the intake of Pb in breast milk was 1,6 mg on average. So the average content of lead in mother's milk was 0.011 μg/cm^3. Research undertook by Conti and Cavolita [4] encouraged us to appreciate their results.

For breast-fed infants, breast milk exposed to Pb (due to the ability to achieve high level of lead in breast milk – up to 12 μg/dm^3) may be harmful. In the human body lead compounds are excreted primarily in the urine (76%), feces (16%) and breast milk (8%) [5, 6].

Iron, zinc and copper concentrations in milk at postpartum are not associated with maternal mineral status, which indicate active transport mechanisms in the mammary gland for all 3 minerals. Iron contents decrease in milk and zinc contents increase during breast feeding. The results of Se, Zn and Cu determination in breast milk samples demonstrate decline in their concentration along with advancing stages of lactation. Wąsowicz et al. found out that Se, Zn and Cu concentrations were the highest in colostrums (n = 43) and amounted to 24.8 ± 10.1 μg, and 8.2 ± 2.8 μg, and 0.45 ± 0.11 μg, respectively. The content of all determined microelements declined significantly during the time of lactation. Statistically significant linear correlation was between concentrations of Zn in blood plasma and milk during the first stage of lactation. Weak but statistically significant linear correlations were also between Se content in plasma and in transitional and mature milk of breast-feeding women [7].

Higher content of metals in the air of Katowice city compared to Cieszyn town and the surroundings was also indicated. The measuring sites close to transport routes of big car traffic did not record significant differences in both of the above towns. The resulting levels of metals in various biological assays confirmed a higher environmental risk posed to mothers in Katowice city [8]. Similar observations were made in relation to smoking addicting mothers and non-smokers, and the observations strongly indicated adverse effects of such addiction. The content of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn in selected biological samples are comparable to those in Polish and foreign literature. There is a confirmed link between metals contaminating environment and metal content in breast milk. The increased metal content in breast milk has many adverse effects on biological quality of an offspring, also in terms of long-term effects in maturity [8, 9].

MATERIALS AND METHODS

Samples were collected from 265 non working mothers in the period of subsequent following lactation days. The mothers were from 16 to 40 years old and lived in the following towns: Częstochowa n = 80, Katowice n = 79, Chorzów n = 15, Cieszyn n = 76 and Tarnowskie Góry n = 15 in the years 2005–2010.

Fig. 1. Dwelling places of mothers participating in the research – Silesia Province

Ryc. 1. Miejsce zamieszkania matek uczestniczących w badaniach – woj. śląskie

The social and economic conditions of these mothers were comparable. Samples of milk, 20 cm^3 each, were taken before morning feeding in the first, second, third day or during the following days of

lactation and stored in small polyethylene containers at −20° C. The mineralization of breast milk samples – 5 cm^3 took place in a mixture of 2.5 cm^3 65% HNO_3 and 1 cm^3 70% $HCIO_4$ (both Merck Supra pure grade) in a microwave heater – Milestone MLS – 1200 MEGA, Running the rotor HPR – 600/10 (10 points). The method was as follows:

Table I. Stages of mineralization
Tabela I. Etapy mineralizacji

Step	Time [min]	Electric Power [W]
1	5	250
2	1	0
3	6	450
4	4	550
5	1	700

The analytical procedure was repeated threefold for each sample. The content of Cu, Cd, Pb, Zn, Ni, Mn and Fe were determined by atomic absorption spectrometry by a VARIAN Techtronic Instrument type 5 DA. Calibration was based on the standard SRMs 1549 (milk powder). The determination of elements in reference material in comparison to the values declared differed by 7%.

Statistical results were calculated by Statistica PL v. 7.0 Software. The nonparametric U Mann-Whitney test used to evaluate the statistical significance of the data and probability ⩽0,05 was considered as significant. The possible relationship between variables were described with the Pearsons's correlation coefficient ($p < 0,05$).

RESULTS AND DISCUSSION

The range of research comprised of the following issues:

- determination of certain elements concentration in breast milk,
- determination of concentrations change as a function of lactation time,
- investigation of co-occurrence of metals in breast milk,
- the effect of tobacco smoking on the occurrence of heavy metals in breast milk – table II.

The results of heavy metals in breast milk for Katowice, Tychy, Częstochowa, Cieszyn, are presented in table III. During the days of feeding the babies particular elements have changed very little in breast milk in the range of 20% in comparison to mean concentration.

Table II. Content of some elements in breast milk (smoking and non smoking women) taken of each day during first two weeks of feeding
Tabela II. Zawartość niektórych pierwiastków w mleku kobiet (palących i niepalących) pobranych w ciągu pierwszych dwóch tygodni karmienia

	Mean content µg/g n = 265	Mothers – non smoking µg/g, n = 167	Mothers – smoking µg/g, n = 98
Al	0.161	0.143 p⩽0.04	0.167
Ba	0.026	0.022 p⩽0.01	0.014
Cd	0.002	0.002	0.002
Cr	0.019	0.019 p⩽0.05	0.026
Cu	0.386	0.402 p⩽0.08	0.422
Fe	0.661	0.490 p⩽0.01	0.661
Li	0.004	0.004	0.003
Mg	29.41	36.35 p⩽0.05	31.93
Mn	0.006	0.006 p⩽0.05	0.012
Ni	0.032	0.020 p⩽0.01	0.041
Pb	0.014	0.010 p⩽0.02	0.020
Zn	3.291	3.313	3.291

p – probability ratio

p – współczynnik prawdopodobieństwa

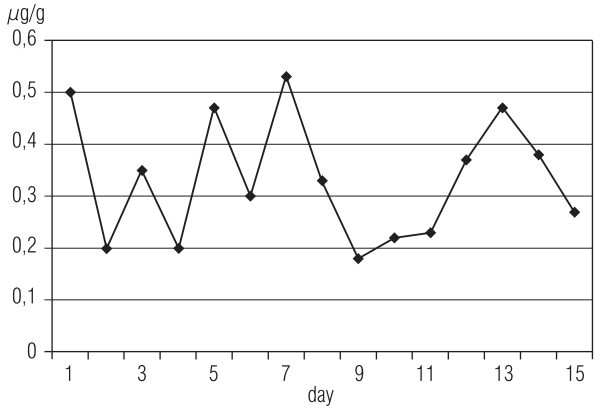

Fig. 2. Change of Cd concentration in breast milk in function lactation time (24 h each day)
Ryc. 2. Zmiana stężenia Cd w mleku kobiet w funkcji czasu laktacji (w ciągu każdej doby)

The results of occurrence of heavy metals in milk from smoking and non smoking mothers presents table IV (Cieszyn, Częstochowa, Katowice). Higher concentrations of heavy metals were found in milk from smoking mothers and did not depend on the dwelling place. It must be pointed out that the level of heavy metals in milk from non smoking mothers reflects the level of environmental hazard. For example cadmium content in the milk of a non smoking mother was 2.6 times higher and in milk

of smoking mother 4.6 times higher than the content of the element in the air – fig. 2. The observed tendency of occurrence of some heavy metals in breast milk for example has changed very much in the function of lactation's time for Cd, Pb, Zn. The influence of environmental threat, for example, towards the woman residing in Cieszyn town, is illustrated by the data presented in fig. 3–4. Characteristic feature for the run of change of metal content in breast milk as a function of mothers residence as well as lactation time metals content fluctuate around the mean value to a great extent – fig. 4.

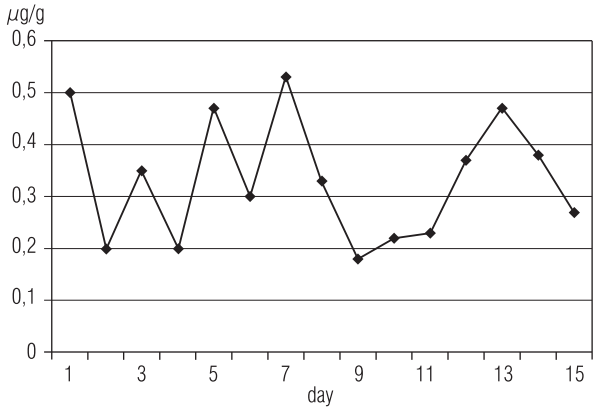

Fig. 3. Change of Zn concentration in breast milk in function lactation time (24 h each of day)

Ryc. 3. Zmiana stężenia Zn w mleku kobiet w funkcji czasu laktacji (w ciągu każdej doby)

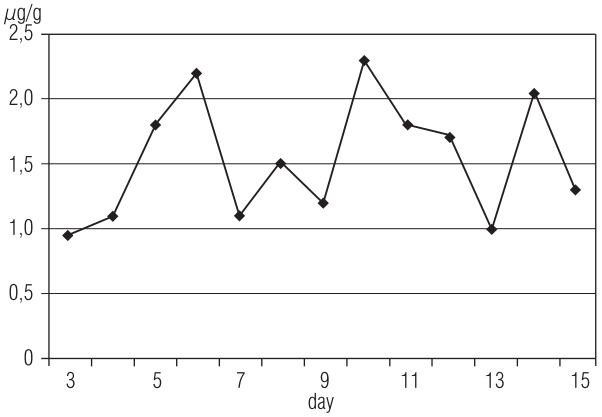

Fig. 4. Change of Pb concentration in breast milk in function lactation time (24 h each of day)

Ryc. 4. Zmiana stężenia Pb w mleku kobiet w funkcji czasu laktacji (w ciągu każdej doby)

Table III. Content of metals in breast milk, in first, second, third of lactation day, μg/cm^3

Tabela III. Zawartość metali w mleku kobiet, w ciągu pierwszego, drugiego, trzeciego dnia laktacji, μg/cm^3

Day	Location	Zn μg/cm^3	Fe μg/cm^3	Cu μg/cm^3	Cd μg/cm^3	Pb μg/cm^3	Mg μg/cm^3	Ca μg/cm^3
1	Tychy (n = 31)	13.42±5.34	0.82±0.44	0.48±0.23	2.94±0.48	1.54±0.35	24.78±1.55	119.31±37.19
	Częstochowa (n = 33)	9.47±4.08	0.95±0.25	0.63±0.21	3.55±0.32	1.45±0.41	28.68±3.19	132.53±22.19
	Katowice (n = 38)	10.43±3.65	1.28±0.63	0.48±0.34	5.89±0.95	1.98±1.42	23.24±4.45	115.27±31.85
	Sosnowiec (n = 28)	12.81±4.78	0.96±0.29	0.29±0.16	2.27±0.89	1.09±1.04	30.88±6.43	147.22±27.51
	Cieszyn (n = 31)	5.01±2.99	0.29±0.26	0.65±0.18	2.64±0.19	1.09±0.51	28.30±3.49	138.68±28.57
2	Tychy (n = 31)	12.85±6.75	0.74±0.21	0.54±0.18	3.99±0.52	1.52±0.40	25.82±4.10	127.40±24.40
	Częstochowa (n = 33)	12.38±5.15	1.03±0.51	0.59±0.22	4.12±0.97	1.48±0.41	26.55±3.79	113.05±19.57
	Katowice (n = 38)	10.27±3.45	1.40±0.76	0.50±0.32	3.34±0.47	1.31±0.23	25.22±4.18	125.92±32.47
	Sosnowiec (n = 28)	9.65±4.85	1.04±.43	0.36±0.24	1.18±0.45	0.75±0.42	27.53±5.78	146.55±35.52
	Cieszyn (n = 31)	4.73±1.79	0.25±0.13	0.53±0.14	3.64±0.86	1.01±0.53	26.41±1.51	137.30±39.77
3	Tychy (n = 31)	12.44±5.52	0.77±0.17	0.60±0.26	1.65±0.42	1.38±0.29	25.71±3.41	135.24±23.14
	Częstochowa (n = 33)	9.52±3.15	0.86±0.31	0.57±0.19	2.94±0.86	1.44±0.42	27.10±2.25	120.92±19.86
	Katowice (n = 38)	10.15±3.20	1.08±0.60	0.60±0.35	2.09±0.63	1.12±0.47	23.09±4.37	119.61±28.73
	Sosnowiec (n = 28)	9.03±4.67	0.96±0.32	0.34±0.20	2.19±0.23	0.91±0.234	25.85±4.37	155.88±23.70
	Cieszyn (n = 31)	5.07±1.88	0.22±0.16	O.54±0.16	3.05±0.46	0.87±0.38	26.16±1.72	140.14±36.83

Table IV. Heavy metals content in breast milk in selected cities (μg/cm^3)
Tabela IV. Zawartość metali ciężkich w mleku kobiet w wybranych miastach (μg/cm^3)

	Cities		Zn	Fe	Cu	Cd	Pb	Mg	Ca
Smoking mothers (n = 98)	**Częstochowa** (n = 33)	Arithmetic mean	10.24	1.03	0.62	3.91	1.48	28.31	121.51
		Standard deviation	7.43	0.38	0.18	2.56	0.40	3.12	23.83
		Variable coefficient	73%	37%	28%	66%	27%	11%	20%
	Katowice (n = 37)	Arithmetic mean	9.53	1.53	0.4	4 4.13	1.64	24.96	125.75
		Standard deviation	3.68	0.61	0.20	5.02	1.19	3.57	36.27
		Variable coefficient	39%	40%	45%	121%	73%	14%	29%
	Cieszyn (n = 28)	Arithmetic mean	4.95	1.24	0.56	3.23	0.95	27.12	139.68
		Standard deviation	2.48	0.18	0.15	2.46	0.50	2.51	36.15
		Variable coefficient	50%	75%	28%	76%	53%	9%	26%
Non smoking mothers (n = 137)	**Częstochowa** (n = 47)	Arithmetic mean	11.34	0.63	0.49	2.04	1.36	23.99	124.79
		Standard deviation	1.80	0.19	0.28	1.19	0.44	1.38	12.49
		Variable coefficient	16%	30%	58%	59%	33%	6%	10%
	Katowice (n = 42)	Arithmetic mean	11.42	0.84	0.65	3.23	1.21	22.19	112.05
		Standard deviation	2.68	0.56	0.45	2.19	0.18	5.06	19.32
		Variable coefficient	23%	67%	70%	68%	15%	23%	17%
	Cieszyn (n = 48)	Arithmetic mean	4.88	0.32	0.65	2.66	1.15	26.33	134.79
		Standard deviation	1.29	0.23	0.20	1.24	0.35	2.80	31.89
		Variable coefficient	26%	74%	30%	47%	31%	11%	24%

Arithmetic mean – *średnia arytmetyczna*
Standard deviation – *odchylenie standardowe*
Variable coefficient – *współczynnik zmienności*

Essential correlation coefficients higher than 0.5 regarding co-occurrence of these metals in the air depicts table IV. As far as Katowice is concerned collected samples show high interdependence of occurrence between: Pb and Zn (0.88), Pb and Cd (0.66), Pb and Ni (0.56), Zn and Cr (0.82), Zn and Ni (0.88). These dependencies were similar in case of air in Cieszyn, Sosnowiec and Tychy – table V.

The important issue was to analyze the co-occurrence of metals in milk. It was done separately for smoking and non smoking mothers living in Cieszyn. Data presented in table III show that there is a high interdependence of occurrence in smokers' breast milk between: Pb and Zn (0.86), Pb and Fe (0.83), Co and Cu (0.82), Ca and Mg (0.54). Inversely proportional dependence between analyzed metals were found for: Cu and Zn (−0.86), Mg and Zn (−0.84), Ca and Zn (−0.84), Cu and Fe (−0.74), Cd and Fe (−0.59), Mg and Fe (−0.70), Pb and Cu (−0.71), Mg and Pb (−0.77), Pb and Ca (−0.71). The change in tendency in the co-occurrence of examined metals for non smoking mothers was not observed. These conclusions are based on undertaken research of 265 mothers from 5 industrial towns located in Southern Poland.

Table V. Co-occurrence of some heavy metals in breast milk in Cieszyn
Tabela V. Współwystępowanie niektórych metali ciężkich w mleku kobiet w Cieszynie

		Smoking mothers (n = 98)						
Non smoking mothers (n = 167)	Metals	Zn	Fe	Cu	Cd	Pb	Mg	Ca
	Zn		0.80	−0.96	−0.17	0.86	−0.84	−0.84
	Fe	0.28		−0.74	−0.59	0.83	−0.70	−0.48
	Cu	0.05	−0.05		0.04	−0.91	0.91	0.82
	Cd	0.19	−0.07	−0.01		−0.21	0.26	−0.31
	Pb	−0.06	0.17	0.29	−0.24		−0.87	−0.71
	Mg	−0.06	−0.03	0.26	0.26	−0.19		0.54
	Ca	−0.29	−0.25	−0.36	−0.01	−0.38	0.39	

for $r \geq 0.25$ $p \leq 0.05$
$r \geq 0.39$ $p \leq 0.01$
$r \geq 0.5$ $p \leq 0.008$
$r \geq 0.7$ $p \leq 0.000$

CONCLUSIONS

1. Active smoking, passive smoking (environmental tobacco smoke – ETS) and other – then smoke environmental pollutants significantly increase the quality of heavy metals in breast milk.

2. The content of particular heavy metals in the milk of non smoking mothers is close to the mean values reflecting the environmental risk.

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