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*Heavy metal pollution and children morbidity rate  
in the Rejowiec Fabryczny area*

Cement industry, especially over the last decades, discharged to the environment large quantities of contaminants. Extraction of raw materials and cement production resulted in considerable emission of dust. For example, in the eighties, the dust deposition in Rejowiec Fabryczny ranged from 225.5 to 368.4 t/km<sup>2</sup> per year, and the concentration of suspended dust reached 320 µg/m<sup>3</sup> (15). In the late eighties, and in the nineties, Rejowiec Cement Plant S.A. accomplished a complex environment protection project which resulted in a considerable reduction of dust discharge. All technological lines were furnished with highly efficient dust removers. According to the data from the environment report for 2003, dust deposit in the cement plant area in 2001–2002 ranged from 40.5 to 69.0 t/km<sup>2</sup> per year (13). These data indicate that over the last years dust emission to the environment decreased several times. Similarly, also the level of suspended dust decreased.

High dust discharge by the cement plant in the past decades probably affected the environment and human health status. According to the literature, the areas surrounding cement plants show elevated levels of Pb, Cu, Cr and Ni (7), and also Zn and Cd (8). The WIOŚ reports (13, 15), however, lack any data on heavy metal pollution in the cement plant areas in the Lublin region (Chełm and Rejowiec Fabryczny cement plants). Preliminary data on the environment state around the Rejowiec Fabryczny cement plant were presented by Królak and Piłat (9). The data on environment condition around the Chełm cement plant were collected by Jasiewicz and Antonkiewicz (6). The surroundings of both cement plants show similar levels of metals in soil. The data on metal deposition in Rejowiec Fabryczny (9) show that the present metal discharge from the cement plant is low, thus elevated metal levels in the environment (soil, plants) result from considerable pollution in the past.

The high level of dust around the Rejowiec Fabryczny cement plant observed until the mid-nineties of the 20<sup>th</sup> century might have affected the health status of the inhabitants of that region. Among the three abiotic environment components (air, water, soil), humans are affected particularly by airborne factors. Typical diseases related to air pollution include: chronic bronchial disorders, rhinitis, throat and larynx inflammations. Health status of human population is directly related to the environment pollution, infants and children being affected most of all. Among various air pollutants, heavy metals belong to the most dangerous ones. They suppress human immune mechanisms, and induce various physiological disturbances. All metals tend to accumulate in the organism (7, 12).

The present study was undertaken to analyze the levels of heavy metals: Cd, Pb, Cu, Zn, Cr and Mn in Rejowiec Fabryczny soils, raw materials for cement production (marl and chalk), in the final product (cement), and in the dust removed by the electrofilters mounted on the rotary clinker kilns. Morbidity rate of 1–6 years old children examined and treated in the local ambulatory medical center in Rejowiec Fabryczny in 1982 and 2002 was estimated.

## MATERIAL AND METHODS

The samples of soil were collected in June 2003, at 10 sites in Rejowiec Fabryczny, from the upper layer (about 20 cm of depth). Total amount of about 1 kg of soil from non-agriculture sites was sampled for analyses. At the same time, the samples of marl and chalk (raw materials), cement, dust removed by electrofilters mounted on the rotary clinker kilns were obtained from the cement plant.

The soil was air-dried, and passed through the sieves of 1 mm mesh. The 5.0 g subsamples were mineralized for 24 hours in the muffle oven, at 420°C. Then the samples were dissolved in 2 cm<sup>3</sup> of nitric acid and 0.5 cm<sup>3</sup> of 30% hydrogen peroxide solution (analytical grade), blot-filtered (suspension was washed with 10 cm<sup>3</sup> of hot 1M HNO<sub>3</sub> dm<sup>-3</sup>), and diluted to 50 cm<sup>3</sup> with double-distilled water. The concentrations of: Cd, Pb, Cu, Zn, Mn and Fe were measured using AAS technique (Carl Zeiss Jena AAS 30).

The information on children morbidity rates were obtained from the medical records of NZOZ "Eskulap" ambulatory medical center. The analyzed data included 280 case history records of children born in 1976–1981, examined in 1982, and 1,070 case history records of children born in 1996–2001, examined in 2002. The percentage of various diseases, and the share of girls and boys among the diseased children were calculated.

## RESULTS

The average metal concentrations in soil (mg/kg) of Rejowiec Fabryczny area were: Pb – 19.8, Cd – 0.39, Cr – 6.16, Cu – 7.14, Zn – 86.8, Mn 114.4 (Table 1). The average metal levels in raw materials used in cement production (chalk and marl, respectively) were (mg/kg): Pb – 17.2 and 13.9, Cd – 0.53 and 0.52, Cr – 10.3 and 9.95, Cu – 4.72 and 6.13, Mn – 101.6 and 72.7, Zn – 44.2 and 29.6, while their concentrations in cement were: Pb – 101.9, Cd – 1.85, Cr – 35.4, Cu – 42.2, Mn – 304.9 and Zn – 292.0. The dust removed by the electrofilters contained high levels of Pb – 1945.5 mg/kg, Zn – 582.9 mg/kg, and Mn – 218.0 mg/kg. Concentrations of Cd, Cr and Cu were below 100 mg/kg: 95.5, 65, and 65.6 mg/kg, respectively (Table 2).

Table 1. Concentrations of heavy metals in soil (mg/kg) in the Rejowiec Fabryczny area

	Pb	Cd	Cr	Cu	Zn	Mn
Arithmetic mean	19.8	0.39	6.16	7.14	86.8	114.4
Geometric mean	16.3	0.32	3.6	4.70	61.6	111.4
Median	14.2	0.28	3.4	4.80	72.2	113.1
SD	12.8	0.28	2.9	5.17	65.3	26.6
Min	7.0	0.14	2.03	2.44	40.9	64.3
Max	42.0	0.92	15.4	21.3	249.0	153.8
Variation coefficient	64.6	71.8	47.2	72.4	75.2	22.9

Table 2. Concentrations of metals (mg/kg) in raw materials used in cement production, in cement, and in dust removed by electrofilters of the Rejowiec Fabryczny cement plant

	Pb	Cd	Cr	Cu	Zn	Mn
Chalk	17.2	0.53	10.3	4.72	44.2	101.6
Marl	13.9	0.52	9.95	6.13	29.6	72.7
Cement	101.9	1.85	35.4	42.2	292.0	304.9
Dust	1945.5	95.5	65.0	65.6	582.9	218.0

Analysis of medical records for 1–6 years old children examined in NZOZ "Eskulap" in Rejowiec Fabryczny in 1982 and 2002 revealed that among 280 children examined in 1982 35% cases concerned

upper respiratory tract diseases, 47.3% – lower respiratory tract diseases, 2.2 % – skin disorders, 10.1% – respiratory system, 5.4% – other diseases. In 2002 the frequency of various diseases was as follows: asthma – 2%, upper respiratory tract – 44.5%, lower respiratory tract – 35%, skin – 9.5%, digestive system – 5.9%, other diseases – 5.1% (Table 3).

Table 3. Morbidity rate of 1–6-year-old children (frequency of various diseases) in 1982 and 2002

Disease	Year	
	1982	2002
Upper respiratory tract	35	44.5
Lower respiratory tract	47.3	35.0
Asthma	non-observed	2.0
Skin	2.2	9.5
Digestive tract	10.1	5.9
Other	5.4	5.1

Among the children examined in 1982, the infants born in 1981 were the most numerous (29%), while the least numerous were the 6-year-old children (6%). The share of children born in the years 1996–2001 ranged from 14 to 22%, the youngest infants being the most numerous. The share of 6-year-old children was similar to the percentage of 3-year-old ones (about 14%). Percentage of 4- and 5-year-old children was also similar (about 15%) (Table 4). The percentage of boys was higher comparing to the girls: 54.7% in 1982, and 52.7% in 2002 (Table 4).

Table 4. Percentage of various age and sex groups among the examined children

Age (years)	Year	
	1982	2002
1	29.0	22.0
2	24.0	19.5
3	18.0	14.3
4	10.0	15.0
5	12.0	15.2
6	7.0	14.0
Boys	54.7	52.7

## DISCUSSION

The concentrations of heavy metals in the upper layer of soil in the Rejowiec Fabryczny area followed the order  $Mn > Zn > Pb > Cu > Cr > Cd$ . The concentrations of three elements: Pb, Cd, Zn were elevated comparing to the reference values (3). It is noteworthy that the concentrations of Zn, Cd, Pb and Cu were higher than the average levels of these elements in soils of Poland (14). The soil around the Rejowiec Fabryczny cement plant contained the similar level of Pb, and slightly lower levels of Cd, Cu and Cr comparing to the Chełm cement plant surroundings (compare the data in Table 1 and 5).

Besides the energetic processes, dust discharged by the Rejowiec cement plant is the source of heavy metals in this region. The level of heavy metals in cement produced in this plant is considerably higher than in the soil. It is also several times higher comparing to the concentrations of these elements in raw materials (marl and chalk) (Table 2). The obtained results show particularly high levels of Pb and Cd in dust removed by the clinker kiln electrofilters, comparing to the concentrations of these metals in raw materials and cement. Among the analyzed metals, these two elements show the lowest melting temperatures, thus their emission is particularly high under high temperature conditions. Installation of electrofilters undoubtedly reduced not only dust discharge from the cement plant, but also diminished emission of these toxic metals.

Table 5. Metal concentrations in soils (mg/kg), according to various authors

	Pb	Cd	Cr	Cu	Zn	Mn
Reference values in Poland (Czarnowska 1996)	9.8	0.18	27.0	7.10	30.0	289.0
Geometric mean of metal levels in soils of Poland (Terelak et al. 2000)	13.6	0.21		6.5	32.4	
Chełm cement plant surroundings (Jasiewicz and Antonkiewicz 2003)	19.68	0.58	13.06	9.86	55.20	31.32

The high level of dust in the environment observed around the Rejowiec Fabryczny cement plant until mid-nineties of the 20<sup>th</sup> century must have affected the health status of the inhabitants. It is obvious that human health strongly depends on the environment quality. Irritating agents present in the air induce particularly respiratory disorders, and very often cause asthma. Air pollutants may also induce various allergies. Chronic exposure to air pollution may result in serious respiratory dysfunction (11).

Over the last 20 years environment quality in the Rejowiec Fabryczny area significantly improved. That was accompanied by a slight improvement of children health status. It is noteworthy that the frequency of respiratory disorders decreased (from 82.3% in 1982 to 79.5% in 2002). Among the youngest children, however, asthma comprised 2% in 2002, which was not recorded in 1982 (Table 3). Asthma is a chronic disease, and its main symptoms include attacks of dry exhausting cough, often occurring at night or early morning, and attacks of dyspnea. This disease is an effect of genetic factors, and adverse environmental conditions (4). It was proved that asthma in children results mainly from adverse environmental factors, e.g. air pollution, and hypersensitivity to allergens. Male sex and low birthweight predispose to this disease. Asthma may develop even in infants. It often follows repeating respiratory tract infections. Usually, the symptoms of asthma develop before the 5<sup>th</sup>-6<sup>th</sup> year of age. In adults the disease may cause even 20% reduction of respiratory parameters (1).

Over the last 20 years, an increase (from 2.2% in 1982 to 9.5% in 2002) in frequency of skin disorders in the youngest children from Rejowiec Fabryczny was observed. Most of them belonged to allergic diseases. The increase in frequency of allergies is related to environment pollution (10) which disturbs immune mechanisms and induces allergic reaction (2). Allergy develops under conditions of exposure to allergens that include various air and soil pollutants, food allergens and dust. In persons predisposed to atopy, environment contamination may induce first symptoms of disease: skin itching and rash or skin dryness. Over the last years, the frequency of allergies in Poland has increased (10).

In our climate zone, children suffer particularly from respiratory system infections that comprise about 75% of all disease cases. High susceptibility of children to respiratory system diseases is also related to their not fully developed immune mechanisms at this age. Respiratory system disorders are usually acute and repeating (5). The obtained data show that children morbidity to respiratory diseases in Rejowiec Fabryczny is higher comparing to other regions. In 1982 the frequency of respiratory disorders in total morbidity rate was 82.3%, while in 2002 – 79.5%. Severe environment contamination, particularly high dust deposition in the past may affect next generations, causing the change in morbidity to particular diseases, and increasing in frequency of those of mutagenic origin. The dust discharged by the cement plant was an abundant source of heavy metal pollution. Some of them, particularly Cd, Pb, Cu and Zn are extremely dangerous to the natural environment. They all show high bioaccumulation rates, are readily absorbed from the digestive tract (Cd, Zn), easily pass through the placenta (Cd, Pb, Zn), bind to sulphhydryl groups of proteins (Cd, Pb), disturb amino-acid chain arrangement (Cd, Cu, Zn), and easily pass through the blood-brain barrier (Pb) (7). Some of them are mutagenic and carcinogenic (12).

Therefore, it would be interesting to compare the morbidity rate, and the frequency of particular diseases in children from Rejowiec Fabryczny with the data obtained from some non-contaminated region, and on the other hand, from another region strongly affected by industrial pollution, such as Upper Silesia.

### CONCLUSIONS

1. The average concentrations of heavy metals in soils of the Rejowiec Fabryczny area were similar to those observed around the Chełm cement plant. The Rejowiec soils contain elevated levels of Cd, Pb and Zn, comparing to the reference values.

2. Installation of electrofilters in the Rejowiec Fabryczny cement plant caused a considerable reduction of lead and cadmium discharge to the environment. Removal of dust resulted also in reduction of Cr, Cu and Zn emission.

3. Adverse environmental conditions in Rejowiec Fabryczny area predispose to respiratory system diseases that are more frequent in this area comparing to the average for other regions.

4. Over the last 20 years, the frequency of allergies and asthma in 1–6-year-old children increased.

5. Morbidity of children was related to their sex, the boys being more susceptible comparing to the girls.

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## SUMMARY

The concentrations of heavy metals (Pb, Cd, Cr, Cu, Mn and Zn) were analyzed in the soils of the Rejowiec Fabryczny area. The levels of these metals were also measured in the raw materials used in cement production, in cement itself, and in dust removed by electrofilters mounted over the clinker kilns. Morbidity rates were also analyzed of children up to 6 years of age examined and treated in the local ambulatory medical center in Rejowiec Fabryczny in 1982 and 2002. The soils of the Rejowiec Fabryczny area showed elevated levels of Pb, Cd, Zn and Cu, comparing to the reference values. Installation of electrofilters in the cement plant resulted in a considerable reduction of Pb and Cd discharge. It was observed that the frequency of respiratory disorders in children from the Rejowiec Fabryczny area was higher comparing to other regions. Over the last 20 years, the frequency of allergies and asthma increased.

### *Zanieczyszczenie środowiska metalami ciężkimi a zachorowalność dzieci na terenie Rejowca Fabrycznego*

Badano zawartość metali ciężkich (Pb, Cd, Cr, Cu, Mn i Zn) w glebach na terenie Rejowca Fabrycznego. Określono także zawartość tych pierwiastków w surowcach używanych do produkcji cementu, w cemencie oraz w pyłach zatrzymywanych na elektrofiltrach zainstalowanych na piecach wypalania klinkieru. Ponadto analizowano zachorowalność dzieci w wieku do 6 lat, zgłaszanych do przychodni rejonowej w Rejowcu Fabrycznym w latach 1982 i 2002. Na terenie Rejowca Fabrycznego odnotowano w glebie podwyższoną w stosunku do wartości referencyjnych zawartość Pb, Cd, Zn i Cu. Zainstalowanie elektrofiltrów na liniach technologicznych w cementowni przyczyniło się do wyraźnego ograniczenia emisji Pb i Cd. Ustalono, że zachorowalność dzieci na choroby układu oddechowego na terenie Rejowca Fabrycznego jest większa niż w innych regionach kraju. W ciągu ostatnich 20 lat zauważa się wzrost schorzeń alergicznych i astmy.