LEAD CONTAMINATION OF ENVIRONMENT AND ITS HEALTH EFFECTS IN CHILDREN DWELLING IN THE VICINITY OF COPPER SMELTERS IN THE SVERDLOVSK REGION

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Abstract
The biggest copper smelters accounting for 80% of total lead emissions from industrial sources in Russia are situated in the Sverdlovsk Region. The assessment of health risk from industrial lead emissions is the basis for developing efficient risk management scenarios. Based on multimedia lead monitoring data in 4 Regional towns we predicted an average concentration of blood lead (PbB) and the percentage of children with PbB above the "level of concern" of 10 µg/dl using US EPA "Uptake/Biokinetic Model for Lead – Version 0.99d". We assessed the factual PbB in representative cohorts (885 children). We found that biomonitoring results correlated well with the results of modeling carried out on the basis of multimedia lead monitoring data. We found that the population risk of psychological retardation assessed by the probability of PbB>10 µg/dl was in good agreement with the results of psychological testing. We also noted a higher prevalence of non-infectious diseases in these children. We found a dominating input of the main exposure routes that served as the basis for developing risk management scenarios. On the example of Krasnouralsk we showed the effectiveness of low-cost activities directed at reducing soil, dust and food exposure to lead and increasing the resistance to this exposure proved by the decrease in PbB in children in the first years after the initiation of the program.

Introduction
Lead hazard for children is one of the major environmental health problems in Russia, especially so in towns with industrial sources of lead emissions, copper smelters being the most important.
The main goal of our study was to develop effective lead hazard abatement programs based on risk assessment and epidemiologic research.

Materials and methods
The study was carried out in 4 towns of the Middle Urals (Russia) with different environmental lead levels. Three of these towns (Krasnouralsk, Pervouralsk, Kirovgrad) are situated close to, but at different distances from 3 big copper smelters giving in sum ca. 80% of total lead emissions from all industrial sources in Russia. The town of Kushva is 50 km away from the nearest industrial sources of lead emissions.

For the first 3 towns we had data on lead concentrations in ambient air, drinking water, soil and foodstuff. The data were obtained within a special program of lead measurements in these media. Lead determination in ambient air and drinking water is based on measuring its concentrations by mass spectrometry with inductively coupled plasma and by PaceScan 3000™. Lead concentrations in soil and food were measured by atomic absorption method in Varian spectrophotometer Spectr-AA-300 Z with a graphite cuvette.
We fed these data into the US EPA “Uptake/Biokinetic Model for Lead” Version 0.99d to predict mean blood lead levels (PbB) and the percentage of children aged 3-7 with PbB>10 ug/dl. Actual capillary blood lead levels were measured in all 4 towns electrochemically using the “Lead Care” Blood Lead Test Kit. One of two such biomonitoring surveys conducted in Krasnouralsk was supervised by a CDC team (Rubin et al, Environ. Health Perspect 110:559-562, 2002).
To assess the role of factors that might influence the lead body burden of a child on the individual level, we distributed a special questionnaire on housing conditions, behavioral peculiarities, nutrition etc. The parents of 697 children returned this questionnaire filled out. Then we carried out a multivariant regression analysis to assess the dependence of individual blood lead levels on different variables.

Results
An important addition to the exposure assessment based on monitoring of lead contamination of environmental media are results of a comparative assessment of metal accumulation and lead body burden in children.
Table 1 shows that model predictions proved to be in a satisfactory accordance with actual PbB levels.

Table 1
Blood Lead Levels as Predicted by the Biokinetic Model and as Estimated by Biomonitoring

Town	Modeling or biomonitoring, year, number of children	% of children having PbB>10 ug/dl	Mean PbB±S.E.
Krasnouralsk	**Modeling**	**61.1 %**	**10.7**
	Biomonitoring 1996 (107 children)	64.5 %	11.8±0.5
	Biomonitoring, 1997 (250 children), CDC project	59.5 %	11.2±0.2
Pervouralsk	**Modeling**	**22.5 %**	7.2
	Biomonitoring, 1999 (339 children)	25.9 %	7.4±0.2
Kirovgrad	**Modeling**	**47.5**	10.1
	Biomonitoring, 2000 (135 children)	60.7 %	10.8±0.4
Kushva	Biomonitoring, 2000 (54 children)	22.0 %	7.5±1.1

Psychological testing of children in Krasnouralsk, Pervouralsk, Kirovgrad, and the least polluted Kushva proved that the ranks of cohorts by the testing result and by the percentage of children with PbB > 10 μg/dl coincided. Figure 1 shows the ranking of towns by the percentage of children with PbB > 10 µg/dl and the percentage of children with unsatisfactory results of psychological testing in these towns in the decreasing order.

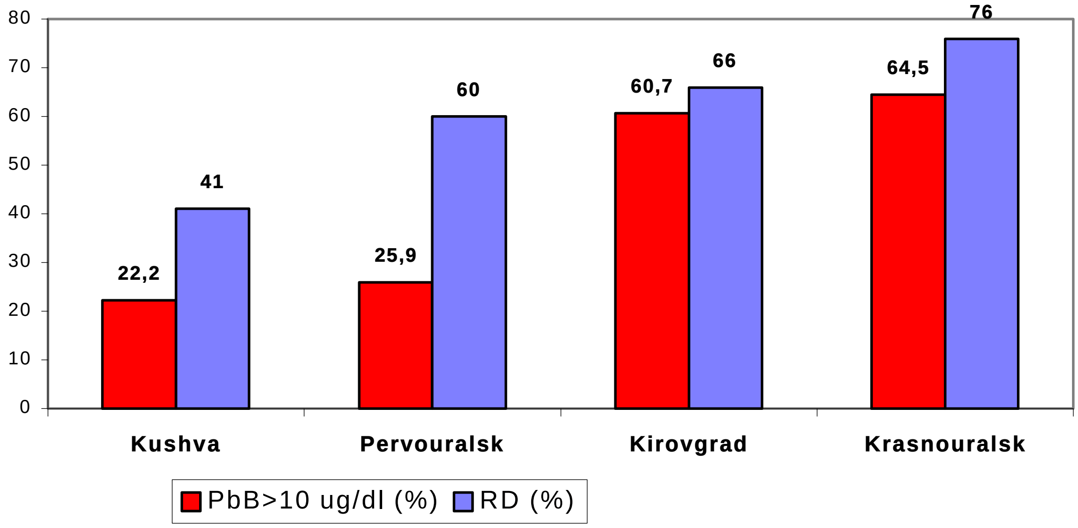

Figure 1. Ranking of towns by PbB>10 ug/dl (% of children) and the prevalence of retarded psychological development (% of children with PD).

Discussion

A plausible interpretation of the result is that, on the population level, the mean environmental lead exposure plays the major part as a determinant of the mean blood lead level and its distribution.
The same modeling showed that the main exposure pathways for environmental lead accumulated in body were those through food and soil/dust, both being far more important than exposures through ambient air and drinking water. The figure demonstrates this result with a typical example of Krasnouralsk.
It is above any doubt that environmental lead contamination is mainly due to lead emissions into ambient air. Nevertheless, children's direct inhalation exposure accounts only for a small part of the total dose. Therefore, although a significant reduction of lead emissions is a priority risk management measure, it does not solve the urgent problem of quick risk reduction, as soil, and thus dust and food contamination with lead remains for a long time. Besides, the cost of this action is very high. It seems obvious that an effective "first aid" program should be aimed at reducing not only just this contamination, let it be only locally, but also a hand-to-mouth transfer of lead from contaminated soil and dust to body.
A supplementary approach to the development of lead hazard abatement programs should take into consideration that, with a given background of environmental pollution, in each population one always finds a wide range of individual PbB values. If one understands why it is so, one can think about individual preventive measures that might reduce lead exposure of, or favorably influence lead toxicokinetics in children.
We believe that the favorable influence of regular milk consumption and intake of vitamins and minerals is mostly due to calcium (in milk), calcium, iron, and zinc (in polyvitamin-polymineral preparations), these metals being well-known toxicological antagonists of lead.

Effective and low cost program of reducing lead risk for children dwelling in lead-contaminated areas should include:

- supplying children with foodstuffs with as low lead content as possible (first of all, with vegetables and milk produced outside lead-contaminated areas);

- decreasing their exposure to soil and airborne soil dust (by cultivating good lawns in kindergartens and other playgrounds, frequently changing fresh sand in sandboxes, repairing asphalted routes and lanes and frequently washing them, and so on);

- decreasing their exposure to indoor dust sediments and dirt brought from outdoors (by frequent washing and vacuum-cleaning all dust-cumulating surfaces in kindergarten and homes);

- hygienic education of children and their parents.

Besides we recommended enriching children's diet with components that favorably influence lead toxicokinetics and/or toxicodynamics:

- milk and other foodstuff rich with calcium plus calcium food additives;
- vegetables rich with pectin plus pectin-containing candies;
- vitamins and trace elements;
- sodium glutamate or an Araliacae preparation enhancing body's resistance to different hazards.

The first town in which such a Program was approved and implemented is Krasnouralsk. Figure 8 shows that both the mean blood lead level and the percentage of children with this level higher than 10 ug/dl were markedly reduced.

Conclusions

1. Environmental lead contamination plays an important role as a determinant of both the mean blood lead level (PbB) in children dwelling in different townships and the percentage of those with PbB>10 ug/dl, but the individual PbB in a child also depends on a set of behavioral, nutritional and housing factors.
2. A lead hazard abatement program for municipalities in vicinity of industrial sources of lead emissions is developed based on assessments of environmental and individual risk factors.
3. A beneficent effect of markedly reducing lead body burden in children as a result of implementation of such a program is demonstrated.