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RELATIONSHIP BETWEEN THE LEVELS OF BIOLOGICAL INDICATORS OF LEAD EXPOSURE IN CHILDREN AND THEIR MOTHERS ENVIRONMENTALLY EXPOSED TO LEAD

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From a follow-up study (1976 – 1985) on lead exposure in population groups living in the vicinity of a lead smeltery, and those from a control area, data were selected on 222 simultaneous measurements of biological indicators of effective lead exposure (absorption) in the blood of children and their mothers. The range of lead exposure levels in both the children and the mothers was very wide (from »normal« to largely excessive lead exposure) as indicated by blood lead (PbB), activity of δ-aminolaevulinic acid dehydratase (ALAD) and erythrocyte zinc-protoporphyrin (ZnPP). A highly significant ($P < 0.001$) exponential decrease in ALAD with respect to PbB, as well as an exponential increase in ZnPP with respect to PbB, was found in children and their mothers. Highly significant ($P < 0.001$) relationships were found between the levels of PbB, ALAD, and ZnPP in the children with respect to those found in their mothers, indicating the relevant influence of a similar microenvironment (e.g. lead in indoor air and in household dust) and life-style (e.g. household hygiene habits and food preferences) on the level of effective individual lead exposure. Although these relationships have indicated generally higher levels of lead in children with respect to their mothers, the hypothesis of a relatively higher absorption and retention of lead in children of a lower age than that in children of a higher age could not be confirmed, which is in agreement with our previous observations. However, when the three subgroups according to the age of the children were compared (i.e. 0.3 – 4.5 years, 5 – 10 years, and 10.5 – 15 years), it appeared that children aged 0.3 – 4.5 years had the lowest lead absorption and those aged 5 – 10 years the highest in relation to their mothers. Within each of these subgroups, a tendency towards relatively higher effective lead exposure in children (i.e. the child/mother ratio of PbB, ALAD and ZnPP levels) with respect to an increase in environmental lead exposure level has been observed.

During the last 15 years numerous literature data have even indicated the harmful effect of low-level lead exposure (i.e. blood lead <300 μg/L) on neuropsychological function in children, particularly those of the lowest age. This resulted in establishment of air quality standards with decreased air lead levels in many countries, and was practically achieved by decreasing the permissible lead content in motor fuel. Although enviromental health criteria are usually aimed at protecting population segments with the highest health risk, i.e. children in the case of lead exposure, it becomes evident that decreasing the air lead level was not sufficiently effective, possibly because of the profound influence of other relevant factors which have been shown to determine actual individual lead exposure in children. The reasoning for decreasing permissible air lead concentration was mainly based on the assumption that: a) children of lowest age are the most susceptible to the neurotoxic effects of lead, and b) in children of lowest age the absorption and retention of lead is higher than that in children of higher age (and particularly than that in adults) at a comparable level of environmental lead exposure. The latter assumption was primarily based on result obtained in experimental animals, although most of the published epidemiological data in children have failed to confirm this hypothesis (1 – 9). On the other hand, epidemiological studies in children have shown that effective individual lead exposure greatly depends on the behavioural characteristics and life-style (including socio-economic status) of the population examined, e.g. at the same level of environmental lead exposure (particularly regarding air lead concentration) large interindividual differences in the level of biological indicators of effective lead exposure (absorption) have been observed. However, since factors other than age *(per se)* appear to have a more profound role in determining the level of effective individual lead exposure, they should be identified and certainly taken into account when establishing preventive measures for decreasing the risk of lead neurotoxicity in children.

According to our results on regular environmental monitoring, as well as biological monitoring of lead exposure in population groups living in the vicinity of a lead smeltery (10 – 16), several factors influencing effective individual lead exposure in children have been identified. Very similar levels of biological indicators of lead exposure have been found in housewives and their children, as opposed to considerably different levels in employed women and their children, i.e. higher lead in children than in mothers (10). Both the pre-school, and school age children whose fathers are occupationally exposed to lead were found to have significantly higher lead exposure than the children whose fathers are not occupationally exposed to lead (12). Sensitive biological indicators of lead exposure have indicated an exponential increase in the effective exposure of children and adults with respect to the proximity of their homes to the lead emission source (11). The concentration of lead in household dust has been found to significantly influence the level of effective lead exposure in children of both pre-school and school age (10, 12, 16). However, our data consistently indicated higher lead levels in school children, i.e. those aged >6 years, than those of lower age (those aged <6 years) (12, 15, 16), and thus could not confirm the hypothetical impact of higher absorption and retention of lead in children of the lowest age range.

In the present study an attempt has been made to control, i.e. minimize the influence of most of the observed relevant factors which determine the level of effective individual lead exposure in children. In agreement with our previous observations, it is assumed that a microenvironment (e.g. lead in indoor air and in household dust) and some relevant aspects of life-style (e.g. household hygiene habit and food preferences, regarding not only the different lead content in various foods but also the influence of other dietary factors on the extent of gastrointestinal lead absorption) are similar in children and their mothers. Therefore the possible influence of the age of children on the extent of absorption and retention of lead has been considered by comparing the levels of biological indicators of lead exposure in different age groups of children relative to those in their mothers. Since our previous data have also indicated the probability that at higher environmental lead exposure the impact of increased effective lead exposure in children relative to their mothers is more pronounced, data were selected to cover a wide range of exposure levels. Such a wide range is regarded useful because it should enable better insight into possible differences not only with respect to the age of children, but also with respect to the level of environmental lead exposure itself.

SUBJECTS AND METHODS

For the period 1976–1985 data were selected on 222 simultaneous measurements of blood lead (PbB), activity of δ-aminolaevulinic acid dehydratase (ALAD), erythrocyte zinc-protoporphyrin (ZnPP) and blood haemoglobin (Hb) in children (aged 0.3–15 years) and in their mothers (aged 20–56 years) living at different distances from a lead smeltery situated in the Alpine region of Yugoslavia. Because of the possible interference of anaemia (i.e. influence of impaired iron metabolism on ZnPP, thus decreasing the specificity of ZnPP as a biological indicator of lead exposure), data showing the mother's Hb <120 g/L were excluded from the present study. Out of a total of 222 pairs of children and their mothers, 177 were living in the vicinity of the lead smeltery (within a radius of 4.5 km from the smeltery) and 45 were living in a control area (i.e. at a distance of 25–30 km from the smeltery). It should be stressed that the level of environmental lead exposure in the vicinity of the lead smeltery was considerably higher before 1978, when a new efficient filter was installed in the smeltery stack which greatly reduced the emission of dust into the environment, and promptly reduced air lead concentration (14). Therefore the selected data of subjects examined in the period 1976–1985 cover a wide range of lead exposure levels in both the children and their mothers, since the PbB, ALAD and ZnPP levels showed a considerable (albeit gradual) decrease of lead exposure after 1978 (16). Heparinized venous blood samples were collected simultaneously in the child and its mother. PbB was measured by a modified electrothermal atomic-absorption-spectrophotometric method (17) with calibration performed by the addition of lead standards into human blood (18), with a coefficient of variation (CV) $\leq 5\%$. The accuracy of the method was controlled by participation in the U.K. External Quality Assessment Scheme for blood lead analysis, and our Mean Running Variance Index Score (MRVIS) was generally lower than the average MRVIS for all participants. ALAD activity was measured less than eight hours after blood sampling (blood was stored at $+4$ °C), according to the standardized European method (19), CV$\leq 2\%$. ZnPP was measured by means of

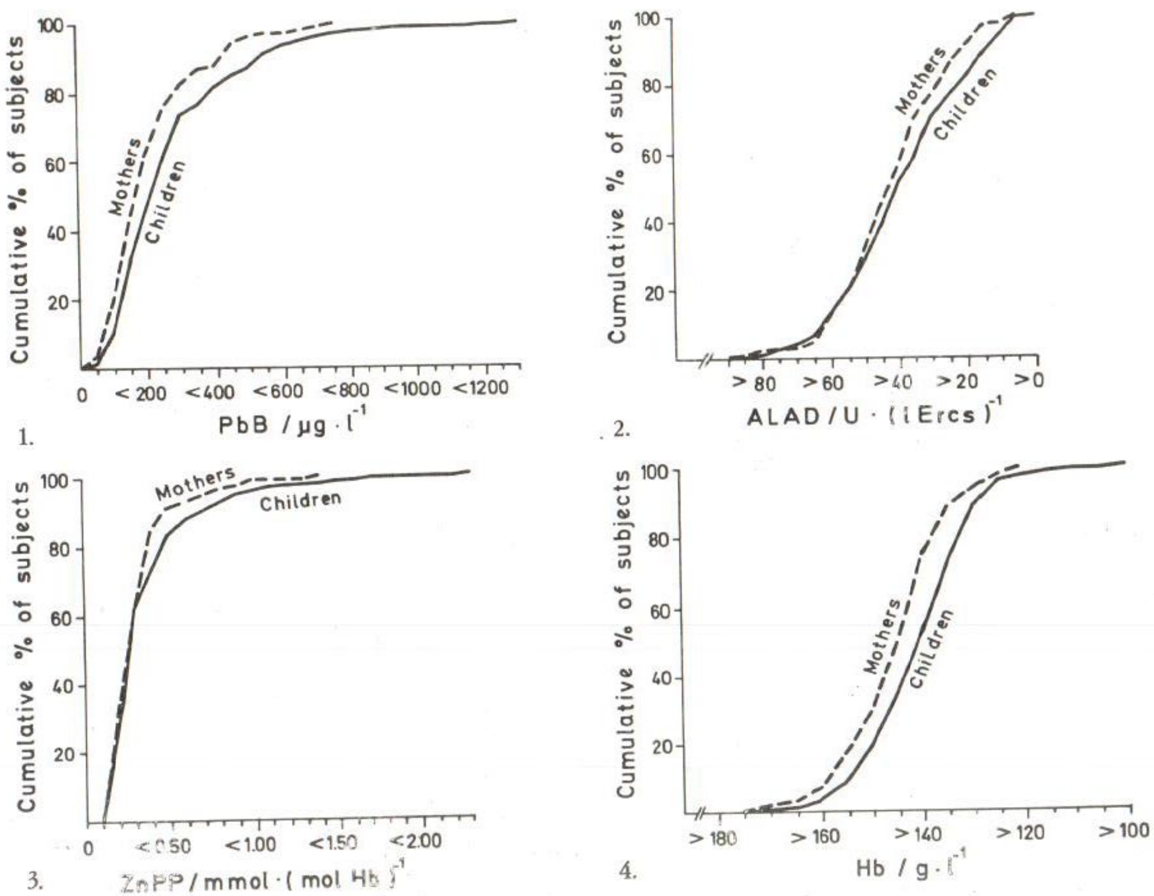
Bell-Aviv haematofluorometer (20) calibrated in mmol ZnPP/mol Hb, CV$\leq$5%. Haemoglobin was measured according to the standardized spectrophotometric method (21) using the ICSH standard blood solutions for calibration, CV$\leq$6%.

All the analyses were performed in duplicate, and the mean values were used for calculations. Regression analysis was applied for the calculation of characteristic semilogarithmic dose-effect relationships between PbB and ALAD, and between PbB and ZnPP, in children and in mothers. The relationships were calculated between the PbB, ALAD and ZnPP levels in children with respect to those found in their mothers. According to the age of children, three subgroups were formed and compared: 1) 45 children aged 0.3–4.5 years, and their mothers, 2) 136 children aged 5–10 years, and their mothers, and 3) 41 children aged 10.5–15 years, and their mothers. The significance of possible difference in slopes and intercepts of these relationships was tested according to Student's t-test.

RESULTS

The cumulative percentage distributions of PbB, ALAD, ZnPP, and Hb in the children and their mothers are shown in Figures 1–4. These data indicate generally higher PbB levels (and lower Hb levels) in the children than in their mothers, whereas the correspondingly lower ALAD levels and higher ZnPP levels in children are less consistently pronounced. However, for 50% of the population there was practically no difference either in ALAD, or particularly in the ZnPP levels of children and mothers. The difference however becomes obvious when the levels of ALAD and ZnPP are compared for 80% and 90% of the population of children and mothers. It should be pointed out that children generally have lower Hb than adults because of physiological reasons, thus the difference in Hb levels between the children and their mothers cannot be attributed to the effect of different lead exposure. However, Hb should never be regarded as a biological indicator of lead exposure (due to the lack of both sensitivity and specificity for lead). However, Hb data can serve as an indication that iron deficiency anaemia has probably not interfered with the specificity of ZnPP for lead in the population studied.

The dose-effect relationships between PbB, as a specific indicator of lead dose, and ALAD and ZnPP, as sensitive indicators of lead exposure and effect, in the children and in their mothers are shown in Figures 5 and 6. A highly significant ($P<0.001$) exponential decrease in ALAD with respect to PbB (log ALAD/PbB) was found in both the children ($r=-0.806$) and the mothers ($r=-0.673$), and the difference between these relationships was not significant ($P>0.60$). The exponential increase in ZnPP with respect to PbB (log ZnPP/PbB) was also highly significant ($P<0.001$) in both the children ($r=0.765$) and the mothers ($r=0.585$), although the correlation coefficients were lower than those of the relationships between ALAD and PbB. The relationships between ZnPP and PbB showed a higher slope in children than in mothers, although the difference was not ($P>0.10$) statistically significant (in both the children and the mothers relatively larger scatter of data was observed in the higher PbB range).



Figures 1 – 4. *Cumulative percentage distributions of the simultaneous levels of PbB, ALAD activity, ZnPP and Hb in 222 children and in their mothers.*

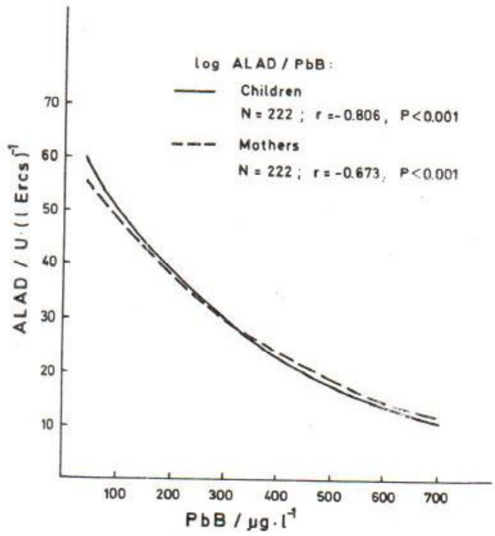


Figure 5. *Relationship between ALAD activity and PbB in 222 children (log ALAD= – 0.0011 PbB + 1.8144) and in their mothers (log ALAD= – 0.0010 PbB + 1.7883).*

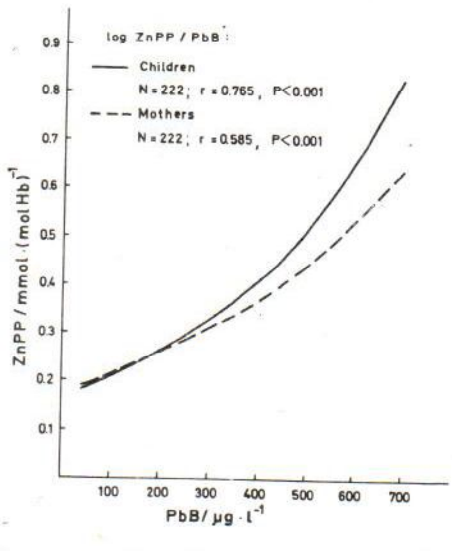


Figure 6. *Relationship between ZnPP and PbB in 222 children (log ZnPP= 0.0010 PbB – 0.7823) and in their mothers (log ZnPP= 0.0008 PbB – 0.7513).*

The relationships between PbB, ALAD, and ZnPP levels in children with respect to those in their mothers are shown in Figures 7 – 9. Since our previous observations have indicated the probability that higher environmental lead exposure levels result in higher effective lead exposure in children relative to their mothers, both the linear and the exponential relationships between the child's and the mother's level of PbB, ALAD and ZnPP were calculated. However, this hypothesis could only partly be supported according to the results of ZnPP, which indicated a slightly higher correlation

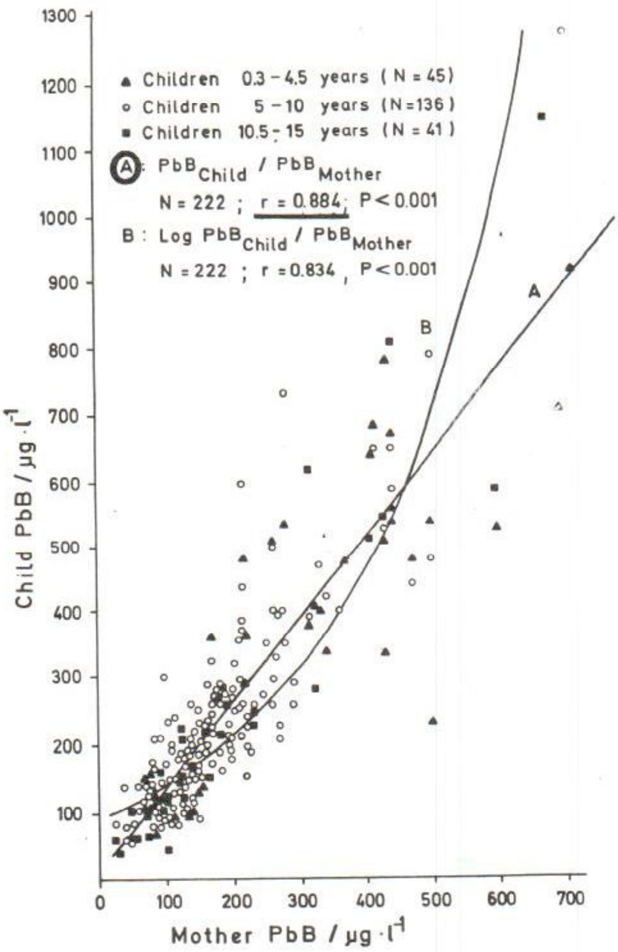


Figure 7. *Relationship between a child's and its mother's PbB levels: A) linear relationship (PbB_{Child} = 1.2603 PbB_{Mother} + 11.0291), and B) exponential relationship (log PbB_{Child} = 0.0018 PbB_{Mother} + 1.9699).*

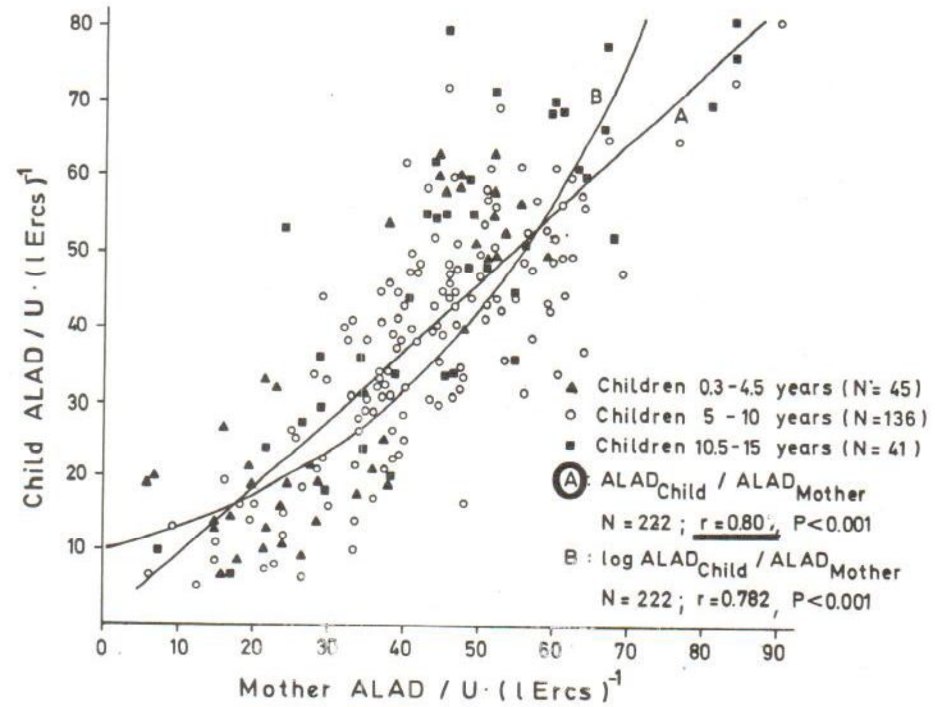


Figure 8. *Relationship between a child's and its mother's ALAD activity levels: A) linear relationship ($ALAD_{Child}$ = 0.9224 $ALAD_{Mother}$ + 0.3367), and B) exponential relationship (log $ALAD_{Child}$ = 0.0128 $ALAD_{Mother}$ + 0.9911).*

coefficient for the exponential increase in the ZnPP levels of children relative to those in their mothers, as opposed to PbB and ALAD which indicated better correlation for the linear relationship between the levels of these indicators in children with respect to mothers. However, all these relationships between the child's and the mother's level of PbB, ALAD and ZnPP were highly significant ($P < 0.001$), and indicated somewhat higher effective lead exposure in children than that in their mothers (as indicated by the slopes of these relationships). However, the scatter diagrams indicate that this general observation is not valid in many individual cases, and is the least consistently indicated according to the levels of ZnPP.

The relationships between the child's and the mother's levels of PbB, ALAD, and ZnPP in three subgroups according to the age of children (i.e. 0.3 – 4.5 years, 5 – 10 years, and 10.5 – 15 years) are presented in Figures 10 – 12. As shown by the linear relationship between the child's and the mother's PbB levels (Figure 10A), significantly lower effective lead exposure was observed in the children aged 0.3 – 4.5 years when compared to the children aged 5 – 10 years ($P < 0.05$), and those aged 10.5 – 15 years

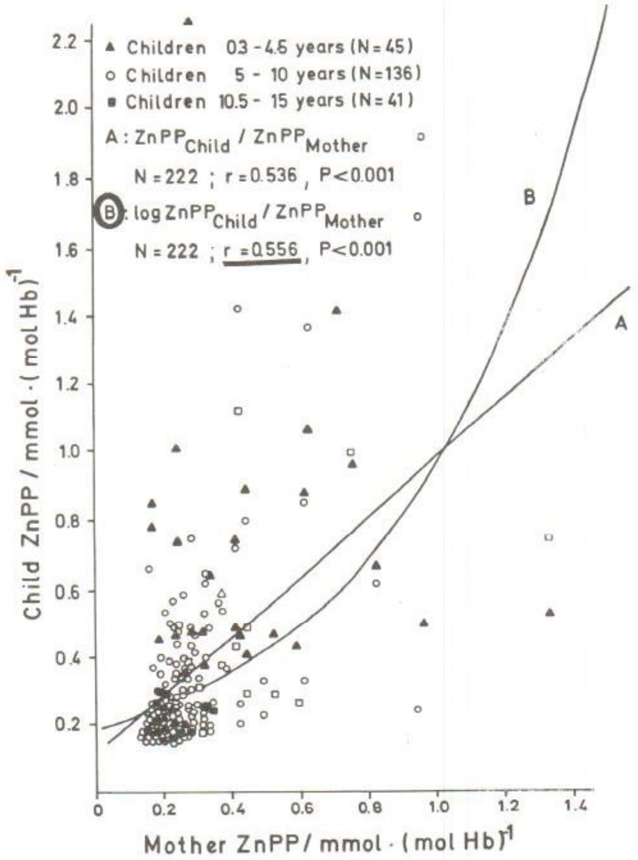


Figure 9. *Relationship between a child's and its mother's ZnPP levels: A) linear relationship* ($ZnPP_{Child}= 0.8711\ ZnPP_{Mother} + 0.1097$), *and B) exponential relationship* ($\log ZnPP_{Child}= 0.7627\ ZnPP_{Mother}= 0.7386$).

($P < 0.02$). The same trend, but no statistically significant difference between the subgroups, was observed for the exponential relationships between the child's and the mother's PbB levels (Figure 10B). No significant difference between the subgroups could be observed according to the levels of ALAD (Figure 11A,B), and the slopes for the linear relationships in each of the subgroups were almost equal to 1 (Figure 11A) indicating generally similar effective lead exposure in children and their mothers. According to the ZnPP levels, children aged 5 – 10 years had the highest effective lead exposure relative to their mothers and those aged 10.5 – 15 years the lowest (Figure 12A,B). For the linear relationships between the child's and the mother's ZnPP levels

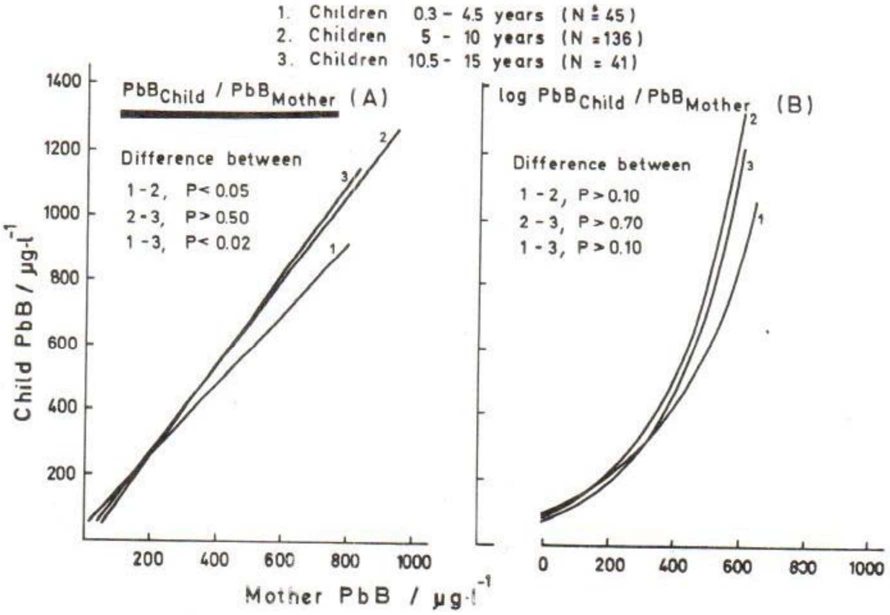


Figure 10. *A and B. A) linear and B) exponential relationships between a child's and its mother's PbB levels within the subgroups according to the age of children: 1) 0.3 – 4.5 years (N= 45), 2) 5 – 10 years (N= 136), and 3) 10.5 – 15 years (N= 41).*

(Figure 12A), a highly significant difference could be observed when the subgroup with children aged 5 – 10 years was compared to the subgroup with children aged 10.5 – 15 years ($P < 0.001$), and less significant when compared to the subgroup with children aged 0.3 – 4.5 years ($P < 0.01$). It should be mentioned that, at the same level of PbB, children generally showed higher ZnPP levels than their mothers (Figure 6), and that only the relationship between the child's and the mother's ZnPP levels within the subgroup of children aged 5 – 10 years (Figure 12A) indicated a slope greater than 1 (i.e. in favour of somewhat higher effective lead exposure in children relative to that in their mothers). However, no statistically significant difference between the subgroups could be observed according to the exponential relationships between the child's and the mother's ZnPP levels (Figure 12B).

With regard to the hypothesis that the extent of effective lead exposure in children with respect to adults may also depend on the level of environmental lead exposure itself, data are presented in Table 1 on the simultaneous measurements of PbB, ALAD, ZnPP (and Hb) in children and their mothers living in the vicinity of the lead smeltery, who were examined in 1976 (high environmental lead exposure), those examined in 1985 (considerably lowered environmental lead exposure), and those living in the control area (very low environmental lead exposure). In addition to the median and

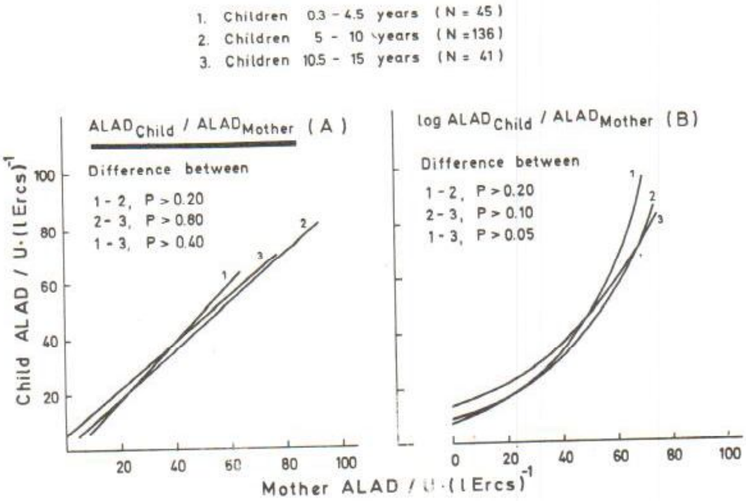


Figure 11. *A and B. A) linear and B) exponential relationships between a child's and its mother's ALAD activity levels within the subgroups according to the age of children: 1) 0.3 – 4.5 years (N = 45), 2) 5 – 10 years (N = 136), and 3) 10.5 – 15 years (N = 41).*

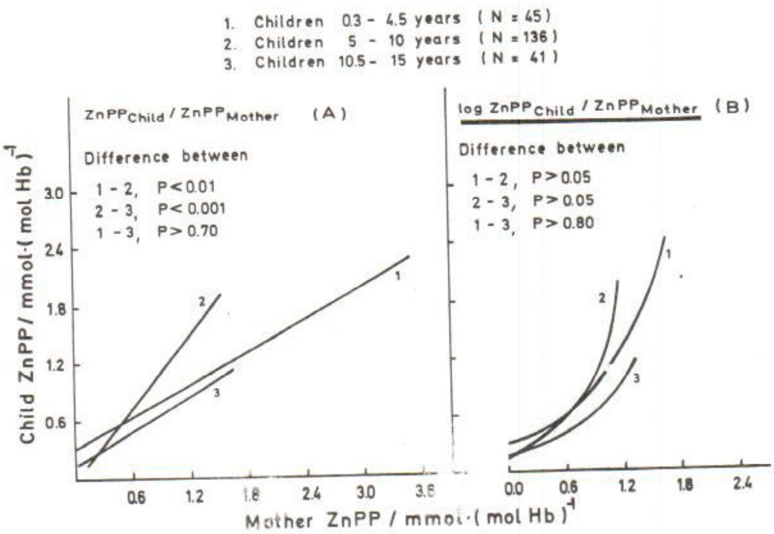


Figure 12. *A and B. A) linear and B) exponential relationships between a child's and its mother's ZnPP levels within the subgroups according to the age of children: 1) 0.3 – 4.5 years (N = 45), 2) 5 – 10 years (N = 136), and 3) 10.5 – 15 years (N = 41).*

Table 1.

Median and range values of biological indicators of lead exposure and/or effect in subgroups of children and their mothers living in the vicinity of the lead smeltery, examined in 1976 (A) and in 1985 (B), and those living in the control area (C). The values of the Child/Mother ratio of the indicators are considered with respect to the age of children, and with respect to the level of environmental lead exposure (i.e. A> B> C).

Biological indicator	The age of children								
	0.3 – 4.5 years			5 – 10 years			10.5 – 15 years		
	The number of examined children and their mothers								
	27	0	18	22	29	14	8	14	13
	Level of environmental lead exposure (A > B > C)								
	A	B	C	A	B	C	A	B	C
PbB (μg/L)									
Children	479 229 – 918	–	112 46 – 161	456 176 – 1273	200 116 – 356	85 55 – 127	570 220 – 1153	162 106 – 268	85 40 – 210
Mothers	411 172 – 711	–	101 67 – 155	305 172 – 700	151 72 – 260	84 25 – 153	422 186 – 688	146 90 – 233	75 25 – 133
Child/Mother PbB ratio	1.26 0.46 – 2.22	–	0.99 0.45 – 2.17	1.45 0.88 – 2.78	1.37 0.70 – 2.10	1.05 0.57 – 3.40	1.26 0.86 – 1.96	1.50 0.94 – 1.77	1.22 0.43 – 2.40
ALAD (U/L Ercs)									
Children	18.7 6.6 – 39.7	–	55.9 44.1 – 63.1	14.1 4.7 – 29.1	43.9 21.4 – 64.7	57.0 46.1 – 81.1	21.9 6.6 – 35.9	51.1 27.5 – 70.2	69.2 52.3 – 81.1
Mothers	22.8 5.7 – 47.9	–	51.6 37.7 – 61.7	23.4 5.7 – 47.9	45.8 32.6 – 67.3	53.9 37.7 – 89.9	28.9 6.8 – 38.1	46.2 26.5 – 64.2	62.8 24.2 – 84.3
Child/Mother ALAD ratio	0.75 0.33 – 3.35	–	1.05 0.71 – 1.42	0.56 0.24 – 1.40	0.90 0.64 – 1.18	0.99 0.80 – 1.58	1.02 0.39 – 1.46	1.06 0.74 – 1.41	1.14 0.77 – 2.18

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Biological indicator	The age of children								
	0.3–4.5 years			5–10 years			10.5–15 years		
	The number of examined children and their mothers								
	27	0	18	22	29	14	8	14	13
	Level of environmental lead exposure (A > B > C)								
	A	B	C	A	B	C	A	B	C
ZnPP (mmol/mol Hb)									
Children	0.59 0.37–2.27	–	0.19 0.17–0.24	0.58 0.37–1.91	0.20 0.15–0.66	0.18 0.15–0.26	0.49 0.26–1.12	0.22 0.16–0.37	0.20 0.17–0.37
Mothers	0.41 0.17–1.33	–	0.18 0.16–0.26	0.32 0.17–0.96	0.18 0.14–0.36	0.19 0.16–0.33	0.48 0.24–1.13	0.21 0.16–0.44	0.21 0.14–0.33
Child/Mother ZnPP ratio	1.60 0.40–8.11	–	1.02 0.77–1.23	1.83 0.76–3.38	1.07 0.65–4.13	1.00 0.54–1.35	1.08 0.44–2.67	1.00 0.53–1.53	1.00 0.54–1.53
Hb (g/L)									
Children	135 104–158	–	133 123–150	144 126–163	137 126–159	136 127–154	151 141–162	144 129–155	143 131–170
Mothers	149 126–171	–	150 135–161	149 138–171	140 122–160	144 129–159	139 126–163	146 120–158	151 136–169
Child/Mother Hb ratio	0.94 0.67–1.13	–	0.89 0.77–1.03	0.96 0.83–1.06	0.98 0.85–1.12	0.95 0.86–1.20	1.07 0.93–1.29	0.98 0.89–1.29	0.97 0.81–1.11

range values of the biological indicators in subgroups of children and their mothers, the child/mother ratio for levels of biological indicators were also calculated. These results indicate a consistent trend towards higher effective lead exposure in children relative to those in their mothers (as shown by the median values for the child/mother ratio) with respect to the increase in environmental lead exposure level. In each of the subgroups according to the age of children (i.e. the only exception is indicated for PbB levels of children aged 10.5 – 15 years), a decrease in values of the child/mother ratio for PbB and ZnPP, and corresponding increase for ALAD, can be observed when comparing data of 1976, 1985, and those from the control area. (The results of Hb are shown only for comparison with the results of ZnPP, since Hb should by no means be regarded as a biological indicator of effective lead exposure, as opposed to ALAD and ZnPP).

DISCUSSION

The present results confirm that effective lead exposure is generally higher in children than in adult women, as indicated by the relatively higher leves of PbB and ZnPP, and lower ALAD, in children with respect to their mothers (Figures 1 – 3, Figures 7 – 9). It has also been confirmed that ALAD and ZnPP are reasonably specific and sufficiently sensitive to be used as biological indicators of lead exposure, due to a highly significant correlation with PbB, and significant changes in ALAD and ZnPP even at a relatively low PbB range (Figures 5 and 6). However, relatively higher effective lead exposure in children with respect to their mothers was better indicated by PbB than by ALAD and ZnPP. This can be explained by the fact that PbB mainly reflects the current (recent) lead exposure level, whereas ALAD and ZnPP better reflect the long-term integrated lead exposure and the accumulated lead at the site(s) of lead effect in the organism (13, 22, 23). Although the current (recent) lead exposure appeared to be higher in the children (as indicated by PbB), the mothers were longer environmentally exposed to lead, thus the long-term integrated lead exposure level in the children and the mothers may be relatively more similar (as indicated by ALAD and ZnPP).

The present results could not confirm the impact of hypothetically higher extent of absorption and retention of lead in children in the lowest age range than those in the higher age range (Figures 10 – 12), since the levels of PbB, ALAD and ZnPP indicated higher effective lead exposure in children aged 5 – 10 years than those aged 0.3 – 4.5 years (and those aged 10.5 – 15 years) when considered with respect to the levels of PbB, ALAD and ZnPP in their mothers. However, our previous data on biological monitoring of lead exposure in children living in the vicinity of the same lead smeltery have repeatedly indicated higher lead exposure in groups of school-age children than those of pre-school age (12, 15, 16). In agreement with our previous observations (10 – 12), the present results indicate that factors other than age-related differences in the extent of absorption and retention of lead have a more profound influence on the level of effective individual lead exposure in children. Our present results (Table 1) agree to a certain extent with the observation of *Duggan* (9), who reviewed PbB variation with age in children and found that in almost all studies concerning PbB differences between children and adults, or younger and older children, »PbB ratio increases as the level of lead contamination increases«. Results of epidemiological studies in children are conflicting with regard to the PbB variation with age, i.e. although some authors have reported a maximal PbB in children aged 2 – 3 years (3, 6), others have found that PbB is independent of age over the age range from four months to 13 years, with a slight decline in children aged 14 years and 15 years (8), or have found no significant correlation between PbB and age below six years, and a slight decline of PbB in age range 6 – 17 years (5), or have even found an increase in PbB with respect to age, year by year, in children aged from eight days to eight years (2). On the other hand, epidemiological studies have consistently indicated that effective lead exposure in children depends on behavioural factors (thus is indirectly dependent of age) and social characteristics of a population examined, e.g. the uptake of lead from dust via dirty hands (resulting in oral intake of lead, particularly in very young children) has been indicated as a most important contributing factor to the child's PbB level (24 – 27). In one comprehensive study on age-specific risk factors for lead absorption in 1041 children living in the vicinity of a lead smeltery (4), it was pointed out that a multifactorial approach to the prevention of excessive lead absorption is required. The same study (i.e. follow-up data) showed that an extensive home hygiene campaign and greater awareness of the health hazard of lead absorption can reduce, or even eliminate, some of the apparently age-specific risk factors in children (4).

In a review article on 19 different studies carried out in 10 different countries (7), it was concluded that it is not possible to establish a reliable relationship between PbB in children and air lead, probably because children (unlike adults who are mainly exposed to environmental lead through inhalation of polluted air) take up lead from the environment through a variety of pathways, thus the living circumstances, access to other pathways, play habits, etc. largely influence the PbB/air lead ratio in children. It was also stressed that the observed large range of the PbB/air lead ratio in children (as indicated by these 19 studies) is at variance with most of the published reviews on the subject, which have tended to conclude that the PbB/air lead ratio for children is much higher than it is for adults.

In conclusion, our results indicate that factors other than age *(per se)* determine the level of effective individual lead exposure in children, and that preventive measures for efficiently decreasing the health risk of lead exposure in children should not only, or mainly, be concentrated on decreasing permissible air lead concentration.

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Sažetak

ODNOS IZMEĐU RAZINA BIOLOŠKIH INDIKATORA EKSPOZICIJE OLOVU U DJECE I NJIHOVIH MAJKI EKOLOŠKI EKSPONIRANIH OLOVU

Iz studije praćenja (1976–1985) ekspozicije olovu u skupinama stanovnika u blizini talionice olova te onih iz kontrolnog područja izabrani su podaci o 222 istodobna mjerenja bioloških indikatora efektivne ekspozicije (apsorpcije) olova u krvi djece i njihovih majki. Raspon razina ekspozicije olovu i u djece i u njihovih majki bio je vrlo širok (od »normalne« do znatno povišene ekspozicije olovu) što su pokazali rezultati olova u krvi (PbB), aktivnosti dehidrataze deltaaminolevulinske kiseline (ALAD) i eritrocitnog cink-protoporfirina (ZnPP). U djece i u njihovih majki nađen je visoko značajan ($P < 0{,}001$) eksponencijalan pad ALAD u odnosu na PbB, kao i eksponencijalan porast ZnPP u odnosu na PbB. Nađeni su visoko značajni ($P < 0{,}001$) odnosi između razina PbB, ALAD i ZnPP u djece i razina istih indikatora u njihovih majki, što upućuje na bitan utjecaj slične mikrookoline (npr. olovo u zraku unutar prostora stanovanja i u kućnoj prašini) i sličnog načina života (npr. navike kućne higijene i sklonost za određena jela) na razinu efektivne osobne ekspozicije olovu. I pored toga što su ovi odnosi pokazali općenito višu razinu olovu u djece nego u njihovih majki, nije bilo moguće potvrditi hipotezu o relativno višoj apsorpciji i retenciji olova u mlađe djece u odnosu na stariju djecu, a to je u skladu s našim ranijim opažanjima. Naime, kada su uspoređene tri podskupine ovisno o dobi djece (tj. 0,3–4,5 godina, 5–10 godina te 10,5–15 godina), pokazalo se da djeca dobi 0,3–4,5 godina imaju najnižu apsorpciju olova, a djeca dobi 5–10 godina najvišu apsorpciju olova relativno prema njihovim majkama. Unutar svake od ovih podskupina opažena je tendencija prema relativno višoj efektivnoj ekspoziciji olovu u djece (tj. kvocijent dijete/majka za razinu PbB, ALAD i ZnPP) u odnosu na porast razine onečišćenja okoline olovom.

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