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A study of pediatric blood lead levels in a lead mining area in South Africa☆,☆☆

Yasmin von Schirnding,[a] Angela Mathee,[b,*] Maurice Kibel,[c] Priscilla Robertson,[b] Nicolene Strauss,[b] and Reinette Blignaut[b]

[a] *World Health Organisation, Geneva, Switzerland*
[b] *South African Medical Research Council, P.O. Box 87373, Houghton 2041, South Africa*
[c] *Child Health Unit, University of Cape Town, Cape Town, South Africa*

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Abstract

This study aimed to determine the blood lead distributions among young children in the lead mining town of Aggeneys in South Africa's Northern Cape Province, and in the comparison community of Pella, about 40 Km away. A further objective of the study was to explore factors associated with elevated blood lead levels. Children aged between 6 and 10 years (average age, 8 years) were studied, 86 from Aggeneys and 68 from Pella. The results showed that blood lead levels among the children of Aggeneys averaged around 16 μg/dL, while in Pella the mean blood lead level equaled 13 μg/dL. Overall, children with raised blood lead levels performed less well at school relative to other children. Within Aggeneys, fathers of "high" lead children tended to shower at work rather than at home, which may have been insufficient to prevent lead from being transported into the home. In conclusion, more stringent environmental control measures are needed, as well as stricter personal hygiene measures, to prevent childhood lead exposure in the mining community.

Keywords: Children; Blood lead; Mining; Environment

1. Introduction

Lead, a metal known since antiquity, occurs ubiquitously in nature. By far the greatest input of lead to the environment, however, has resulted from human activity (Southwood, 1983). Lead was one of the first metals to have been smelted, and lead ores were mined extensively throughout ancient times, mainly for their silver content. From the mining, smelting, and refining of lead, and from the use and production of lead-based products, lead is emitted into the environment and deposited in soil, dust, food, and water. Studies have shown how, over time, lead levels have risen over the whole of the earth's surface, especially since the industrial revolution and the addition of lead additives to petrol (Murozumi et al., 1969). It is now well established that a positive association exists between the degree of urbanization and the incidence of raised blood lead levels in a community.

While in general blood lead levels of rural communities can be expected to be significantly lower than those of urban communities, among populations living in the vicinity of certain industrial sources of lead, such as lead smelters and mines, a higher incidence of elevated blood lead levels may occur, particularly among young children (Murgueytio et al., 1998; Paoliello et al., 2002; Trepka et al., 1997). Workers bringing lead-rich dust into the home from the workplace via their clothes, hair, and shoes (Chiaradia et al., 1997) may put children engaging in hand-to-mouth activities at an increased risk of lead exposure.

Little information is available in relation to the distribution of blood lead levels in children living in and around lead mining towns in South Africa, where three major lead mines are currently in operation. This

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*Corresponding author. Fax: +27-11-717-2493.
E-mail address: amathee@mrc.ac.za (A. Mathee).

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paper describes the findings of a study of blood lead levels and associated risk factors among children attending a primary school in the lead mining town of Aggeneys in South Africa's Northern Cape Province and among those attending a primary school in the comparison town of Pella, around 40 km away. The economic status in Pella, relative to Aggeneys, was low, with poorer housing conditions and limited access to basic environmental health services. Background and risk factor data were collected through the administration of structured questionnaires.

2. Methods

Two communities, namely Aggeneys and Pella, were selected for study. The mining town of Aggeneys is situated 110 km northeast of Springbok and 80 km west of Pofadder in the Namaqualand District of the Northern Cape Province. South Africa's largest deposits of lead occur in the region. The Black Mountain Broken Hill deposit consists of two ore bodies, separated by several meters of barren schist, comprising mainly weakly mineralized ferruginous quartzite, magnetite, and well-mineralized massive sulfide. High lead-to-zinc ratios characterize the massive sulfide lenses in the upper ore body. The principal sulfides are pyrrhotite, galena, sphalerite, pyrite, and chalcopyrite. Significant amounts of silver are found in both the copper and the lead concentrates. An underground mine, concentrator, and ancillary facilities exist for the mining and milling of base mineral deposits at Aggeneys. Lead sulfide, zinc, and copper concentrates are the principal mine products. The town of Aggeneys developed around the mine and at the time of the study accommodated a community of around 3500 people. The town is fully electrified and has a reticulated water supply from the Orange River. The community of Pella is situated about 40 km to the northeast of Aggeneys, close to the Orange River. There is no electricity or reticulated water inside homes, but piped water from the Orange River is accessed through outside taps.

The only primary school for Colored children in each community was included in the study, following permission from the school authorities. In Aggeneys, the mining facilities were located less than 2 km from the study school. Children aged between 6 and 10 years in grades 1, 2, and 3, were included with parental consent. The average age of the children studied in both communities was 8 years. Approximately 10 mL of venous blood was obtained from all children present at school on the day of the study (68 children from Pella and 86 from Aggeneys) and stored on ice in heparin-containing tubes.

Blood lead analyses were carried out by the Institute of Child Health of the Red Cross War Memorial Children's Hospital in Cape Town, which participates in a national quality control program (Röllin et al., 1988). Lead in blood samples was concentrated by chelation with ammonium pyrrolidine dithiocarbamate and extracted into methyl isobutyl ketone. Following centrifugation, an atomic absorption spectrophotometer (Pye-unicam SP9 model, equipped with automatic sampler, graphite furnace, SP9 computer, and a deuterium arc background corrector) was used to perform lead analyses. With each batch of samples a reagent blank and set of working standards were run simultaneously. The coefficient of variation in blood lead samples was 5.8%. Measurements of zinc protoporphyrin levels in the blood (an indicator of possible increased lead absorption) were performed using an AVIV hematofluorometer.

Height and weight measurements were performed on children using a standard bathroom scale according to standard World Health Organization guidelines (WHO, 1985). Due to restricted resources, questionnaires were administered to a randomly selected subsample of about 50% of the children's parents (36 children from Pella and 49 children from Aggeneys), and information was collected on sociodemography, housing conditions, children's behavior (for example, play sites, hand-to-mouth activity, pica), environmental and personal hygiene, and work history of adults in the household.

Wilcoxon two-sample (normal approximation) tests were performed to test for differences in blood lead levels and other blood parameters between the two towns. χ^2 or Fisher's exact tests were preformed to determine the statistical significance between the variables and blood lead status of children living within Aggeneys, using a cut-off point of 18 μg/dL in the distribution of blood lead measurements.

3. Results

The blood lead distributions for Aggeneys and Pella are given in Fig. 1. Statistically significant differences in

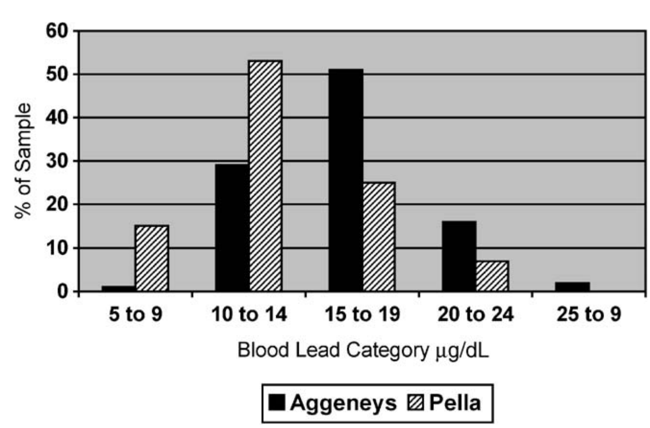

Fig. 1. Blood lead distributions in Aggeneys and Pella.

Table 1
Social parameters within Aggeneys by blood lead concentration

Variable	Aggeneys	Pella
Mean blood lead level	15.9 μg/dL	13.2 μg/dL
Standard deviation	3.675 μg/dL	3.520 μg/dL
Range	9.0 to 27.5 μg/dL	6.0 to 22.0 μg/dL
Mean ZPP	1.78 mg/g Hb	1.64 mg/g Hb
Mean weight	22.27 kg	20.67 kg
Mean height	123.79 cm	121.75 cm
Home > 4 rooms	100%	31%
> 3 children < 5 years	5%	25%
Child "overactive"	58%	36%
Child abnormal mouthing activity	37%	10%
Child failed at school	19%	31%

Table 2
Differences within Aggeneys children by blood lead concentration

	18 μg/dL (group 2)	⩽18 μg/dL (group 1)	Significance level (*P* value)
Father postschool qualification	10.53%	31.58%	0.075[a]
Father showers/ bathes at home	0%	18.92%	0.051[a]
Father showers at work	66.67%	41.03%	0.072[b]
Child failed at school	35%	10.26%	0.033[a]

[a] Fisher's exact test.
[b] χ^2.

blood lead distributions between the two communities were found ($P = 0.0001$). As shown in Table 1, blood lead levels in Aggeneys averaged around 16 μg/dL, with 98% of the population having blood levels ⩾10 μg/dL, the current level in guidelines in the USA. In Pella, the mean blood lead level was 13 μg/dL, with 85% ⩾10 μg/dL. Blood lead levels in Aggeneys ranged from 9 to 27.5 μg/dL and in Pella from 6 to 22 μg/dL. Blood lead levels were not related to age (the mean age in both communities was 8 years) or gender, and both males and females showed significant differences in blood lead concentration between the communities. Small but statistically significant differences in zinc protoporphyrin (ZPP) concentrations also occurred between the two communities, averaging 1.78 and 1.64 mg/g Hb in Aggeneys and Pella, respectively ($P = 0.027$) (Table 1).

With respect to anthropometry, Aggeneys children were slightly taller and heavier than children from Pella (Table 1). In general, the impoverished community in Pella lived in small houses (many of them informal dwellings) that were considerably dilapidated and more densely populated than those of people living in the more affluent Aggeneys, which was fully electrified and had waterborne sewerage. The main sources of fuel in Pella were wood and gas and the "bucket system" was the predominant form of sanitation. More parents of children living in Aggeneys had a high school education (64% versus 43% in Pella) and more Aggeneys fathers had postschool qualifications (25% versus 0% in Pella).

Responses to questions relating to children's behavior revealed that more parents in Aggeneys than in Pella described their children as "overactive", or more active than normal (58% versus 36%, respectively). Thirty-seven percent of the children from Aggeneys, compared to 10% from Pella, were described by their parents as having pronounced hand-to-mouth activities, for example, biting nails, sucking fingers, or putting foreign objects into their mouths. Thirty-one percent of the children from Pella had failed grade 1, compared to 19% at Aggeneys.

Since the blood lead levels of the majority of study children (98% in Aggeneys) equaled or exceeded the Centers for Disease Control (USA) level of 10 μg/dL, further analyses were undertaken to compare differences between the children with the highest compared to those with the lowest blood lead concentrations in the Aggeneys study sample using a midpoint of 18 μg/dL (group 1, ⩽18 μg/dL, and group 2, >18 μg/dL) (Table 2). The results revealed that within Aggeneys, more group 1 than group 2 children had a father with a postschool qualification and that children who had failed a standard at school had higher blood lead levels than other children. Children of fathers/male guardians who showered or bathed immediately upon returning from work tended to have lower blood lead levels. Two-thirds of fathers of group 2 children showered at work, compared to 41% of fathers of group 1 children, and a higher percentage of the former group had their clothes washed at work rather than at home. None of the former group showered immediately upon coming home, whereas 19% of the latter group showered upon coming home.

4. Discussion

The mean blood lead levels of children in both communities tested are higher than would be expected in a rural setting. Blood lead levels at Aggeneys, in particular, which averaged around 16 μg/dL, are more comparable to blood lead levels of Cape Town inner-city children of a similar age and socioeconomic status, among whom a mean blood lead level of 18 μg/dL was measured (von Schirnding et al., 1991), than to what might be expected of children living in rural areas.

Studies of blood lead levels among children living in remote and isolated parts of the world, for example, the Himalayas and Papua New Guinea, have been found to have blood lead levels around 3–5 μg/dL (Piomelli et al., 1980; Poole et al., 1980). In countries throughout the world, particularly where stringent controls on lead have been introduced, blood lead levels have been continuously declining and now average well below 10 μg/dL in the USA and many European countries in both urban and rural areas. The USA considers blood lead levels in the region of 10 μg/dL and above to warrant further investigation. Surveys conducted elsewhere have shown that children living in the vicinity of lead mines or smelters frequently have higher blood lead levels than adults. Studies of communities living in close proximity to smelters in The Netherlands, Belgium, and the United States have had blood lead levels in children averaging around 16, 28, and 40 μg/dL, respectively (Brunekreef et al., 1981; Roels et al., 1980; Yankel et al., 1977). In a study conducted in the Broken Hill (Australia) mining community, however, about 20 percent of children aged 1–4 years had blood lead levels above 25 μg/dL (Gulson et al., 1994). Certain studies conducted in the vicinity of mining areas (Cotter-Howells and Thornton, 1991; Moffat, 1989; Murgueytio et al., 1998; Trepka et al., 1997) have documented blood lead levels lower than 10 μmg/dL, which have been attributed to the low bioavailability of the lead (Steele et al., 1990).

Apart from elevated environmental lead concentrations in Aggeneys as a consequence of natural mineralization and anthropogenic contamination following mining activity over the years, it is a well-established mechanism of childhood lead exposure that workers may transport lead-rich dust into the home environment via their skin, clothes, or hair, thereby providing the opportunity for children to be exposed (Chiaradia et al., 1997). Blood lead levels of Aggeneys workers over the period 1981–1988 averaged around 24 μg/dL (van Heerden and Mets, 1991), with 18.5% of workers having blood lead concentrations >40 μg/dL. The maximum blood lead concentration measured was 80 μg/dL. In the present study, children whose fathers chose not to shower immediately upon returning home from work had higher blood lead levels than other children. Workers in the more dusty occupations (with higher blood lead levels), were more likely to have showered at work, but this may have been insufficient to prevent dust from being brought back into the home environment. Workers in less dusty jobs (more likely to have low blood lead levels) tended to leave the premises with their work clothes, shower at home, and also have their clothes washed at home.

Factors such as the personal hygiene habits of workers may have influenced children's blood lead levels, and is suggestive of a mechanism whereby children may have become exposed to lead rish dust in the home, via the dust-hand-mouth pathway. Workers may have brought lead-rich dust into the home via their hair or clothes, for example, providing a source of exposure for children in the home, particularly those with pronounced hand-to-mouth activities.

Interesting observations were made in this study regarding the relationship between socioeconomic status and blood lead levels. For example, Aggeneys children of higher socioeconomic and nutrition status but more exposed to sources of environmental lead had higher blood lead levels than impoverished, less exposed children living in Pella. Within Aggeneys, however, children from more financially secure homes had lower blood lead levels than other children. von Schirnding has demonstrated that in a South African urban setting, where environmental lead is all pervasive, socioeconomic factors assume importance in influencing the extent to which children are exposed. Thus, urban children of low socioeconomic status generally exhibit higher blood lead levels than urban children of high socioeconomic status. This relationship between socioeconomic status and blood lead levels does not necessarily hold in settings where environmental lead is less pervasive: in our example, children who were of relatively low socioeconomic status but were less exposed (Pella) had lower blood lead levels than their counterparts from Aggeneys, who were of higher socioeconomic status but more exposed. Within the exposed community of Aggeneys however, children of low socioeconomic status had higher blood lead levels than other children.

Additional research is needed to examine in more depth the factors influencing lead exposure in the two communities. Ongoing stringent environmental and personal hygiene control measures are imperative, as is an intensive education program to raise awareness in the community of sources and mechanisms of exposure to lead.

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