Mental capability of children exposed to lead pollution

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Hebel, J. R., Kinch, D., and Armstrong, E. (1976). British Journal of Preventive and Social Medicine, 30, 170-174. Mental capability of children exposed to lead pollution. ‘Eleven-plus’ school examination scores were obtained for 851 Birmingham children residing since birth in a lead-polluted area and 1642 children residing in two similar but unpolluted areas. It was found that the children in the lead-polluted area actually scored higher on the average than children in the control areas. Within the area of lead contamination, children living closest to the source of pollution did not have significantly lower scores than children living further away. The results indicate that lead pollution of the magnitude reported in this investigation did not have a demonstrable effect on the mental capabilities of children in the affected community.

Although no one has any doubt that lead is a poison, considerable doubt still remains as to the extent of the effect of environmental lead pollution on mental development in exposed children. A recent study by Lansdown et al. (1974) on children living in a London community which had become contaminated by lead failed to reveal any such effect. Bryce-Smith and Waldron (1974) and David (1974), however, have cited methodological difficulties with this study and point to papers by David, Clark, and Voeller (1972), Pueschel, Kopito, and Schwachmann (1972), and the United States National Academy of Sciences’ Airborne Lead in Perspective (1971), which suggest that there is an effect.

The study done by Lansdown et al. (1974) showed clearly that the blood-lead levels in children living close to the sources of pollution were higher than those who lived further away. On the other hand, measures of intelligence and behaviour were found not to relate either to the blood-lead level of these children or to the distance of their residence (during the first two years of life) from the source of pollution. However, systematic changes in other aspects of the environment are very likely to occur with increasing distance from a factory site. In so far as factors other than pollution are involved with distance and because such factors could easily be reflected in measures of mental capability such as IQ tests, the effect of lead contamination could either be hidden or exaggerated depending upon the nature of the change. This problem was recognized but not dealt with by Lansdown et al. (1974). Our investigation attempts to take factors related to distance from the factory site into account in a study of school performance of Birmingham children residing in a lead-polluted area and those children residing in two other areas of the city.

Material and Method

Data on Lead Specimens

Since 1972 the City of Birmingham has undertaken an ongoing survey of lead levels in dust samples gathered throughout the city. The purpose of the survey was to establish the background level of lead in various localities and to identify areas with heavy deposits (Reynolds, 1972). Several such areas were found but one in the south central part of the city was chosen for particular study (Area 1). The apparent source of lead pollution was a battery
factory. Samples taken closest to the factory had the highest lead contents (some of these were as high as 4%). Beyond a radius of 275m the samples showed lead levels similar to the normal city atmosphere. Thus children living within 275m of the battery factory were exposed to a high level of lead.

Extensive dust sampling was also done in an area in the north central part of the city (Area 2). Here lead levels were found to be low. In this case a factory engaged in the manufacture of electrical equipment was taken as the reference point. Children living in Area 2 were used as a control group which could be distributed according to distance from a large factory reference point in the same way as in the polluted area. Table I shows the average lead levels in dust samples taken at various distances from the two factories concerned.

### Table I

<table>
<thead>
<tr>
<th>Area in Which Samples were Taken</th>
<th>Distance from Factory (metres)</th>
<th>No. of Samples</th>
<th>Average Lead Level (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1, in vicinity of battery factory</td>
<td>&lt;175</td>
<td>111</td>
<td>4670</td>
</tr>
<tr>
<td></td>
<td>175-275</td>
<td>41</td>
<td>2750</td>
</tr>
<tr>
<td></td>
<td>275-550</td>
<td>27</td>
<td>1740</td>
</tr>
<tr>
<td>Area 2, in vicinity of electrical equipment factory</td>
<td>&lt;175</td>
<td>15</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>175-275</td>
<td>6</td>
<td>1240</td>
</tr>
<tr>
<td></td>
<td>275-550</td>
<td>4</td>
<td>1740</td>
</tr>
</tbody>
</table>

Area 2 offers an environment similar to that found in Area 1. Data from the 1951 census shows that the density of occupied dwellings per acre was 8.3 for Area 1 and 7.9 for Area 2. The population density was 30.8 persons per acre in Area 1 and 29.7 persons per acre in Area 2. A reduction in population density occurred in both areas between 1951 and 1961 (all the children included in the study were born during this period). The 1961 census shows 28.7 persons per acre in Area 1 and 25.1 persons per acre in Area 2.

**DATA ON CHILDREN**

The data used were obtained from information collected at the time of birth for all children born to Birmingham residents in the years 1950-53, and from results of the selective examination taken by 11-year-old Birmingham schoolchildren (11-plus examination) residing in the city during the years 1961-64.

The birth data were described by Leck et al. (1969) and comprise obstetric records with additional information collected mainly by health visitors recorded to the age of five years. Included is a three-category social classification based upon father's occupation which corresponds approximately to classes I and II, III, and IV and V respectively in the Registrar General's classification. Also included is the child's home address at the time of birth.

The data used to assess the mental capability of the children, the 11-plus material, have been described by Barker and Edwards (1967). The examination data consist of two verbal reasoning parts, an English part, and a mathematics part. The score for each part has been corrected for the month in which the child was born to remove the effect of slight variation in age. The data for each child includes the school he attended and his address at the time of the examination.

By linking these birth and 11-plus examination data, Record, McKeown, and Edwards (1969) were able to demonstrate the joint influence of maternal age, birthrank, and social class on the 11-plus examination score. The 11-plus examination score was shown to be associated with maternal age and birthrank within each of the three broad social class categories. It was concluded that this effect was evident because maternal age and birthrank were actually additional indicators of social circumstances. There was also shown to be a small but consistent difference in scores between boys and girls. These findings indicated that in making assessments of intelligence among different groups of children based upon 11-plus examination scores it was important to take into account the variables of sex, maternal age, birthrank, and social class.

**METHOD OF STUDY**

The assembly of groups of children at different risk to lead exposure was as follows:

1. All the junior schools in Areas 1 and 2 were identified, and birth records linked with 11-plus examination scores for children attending these schools were extracted from the files.

2. The address of each child at the time of the 11-plus examination was checked against his address at birth. If these addresses were found to differ enough to indicate that the child's family had moved into the community after his birth the child was excluded from the study. This was done because it was believed that exposure to lead may be most important in the preschool years and no suitable determination of risk could be made.
for children who moved into the community at some unknown time after their birth.

3. The residence of each child was categorized according to the distance from the two factories concerned in Areas 1 and 2. The categories used were:
(a) within 275 metres
(b) 275 to 550 metres
(c) beyond 550 metres.

When a move within the community occurred between the time of birth and the 11-plus examination which involved a change from one of these categories to another, the child was placed in that category which was further from the factory in question.

The above procedure thus defined six groups of children, three related to a factory causing lead pollution and three related to a factory not causing lead pollution. Both factories were operating before 1950. The production of lead oxide at the battery factory began in 1929 at a rate of approximately 70 tonnes per week and has increased to 320 tonnes per week (Aston, 1976). Thus it seems reasonable to assume that the results of the recent survey of lead levels in these areas reflect conditions which were applicable to the first 11 years of life for the children in the study.

It was decided to include still another control group, one which was not associated with a specified factory. For this purpose two adjacent communities on the south east side of the city were chosen (Area 3). This area of the city differs from Areas 1 and 2 in that it is almost entirely residential, but the social mix is similar to that in the other two areas. The children used in the study to represent Area 3 were selected in the same way as for Area 1 and 2, and only those who remained in that area from birth until the 11-plus examination appear in the analysis.

Although the data were collected prospectively, the study design was formally retrospective in that residence in the appointed area at the time of the 11-plus examination was the post hoc criterion for inclusion.

The number of children made available for this investigation by the procedure described was 851 in Area 1, 948 in Area 2, and 694 in Area 3, giving a total of 2493.

RESULTS

Mean final 11-plus examination scores are presented in Table II for each of the groups of children. The final score consists of the sum of scores of the four component examinations, plus an age weighting and a headteacher's ranking. The final score was computed as the sum of the index child's own examination result, and the examination result of another child (from the same school) who achieved the rank previously allocated to the index child by the headteacher. The final score may therefore be regarded as containing not only information from the four examinations, but also information based upon the child's past performance.

Although marked differences in the final scores were found between the three areas, no significant differences were seen to exist within Areas 1 or 2 according to distance from the reference points considered. In Area 1—the lead-polluted area—the children scored higher, on average, than children in either of the other two areas. However, those who lived closest to the battery factory did not score appreciably lower than other children in the area who attended the same schools. It is important to remember that the dust samples indicated no extraordinary lead pollution beyond 275 m of the battery factory.

TABLE II

MEAN FINAL 11-PLUS SCORES ACCORDING TO RESIDENCE OF CHILD, BIRMINGHAM 1961-64

<table>
<thead>
<tr>
<th>Area of Residence</th>
<th>Factory Used as Reference</th>
<th>Metres From Factory</th>
<th>Mean* Score</th>
<th>Number Children</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Battery factory, apparent source of lead contamination</td>
<td>&lt;275</td>
<td>104.9</td>
<td>55</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>275-550</td>
<td>103.8</td>
<td>112</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;550</td>
<td>103.8</td>
<td>684</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>Electrical equipment factory, no lead contamination</td>
<td>&lt;275</td>
<td>99.3</td>
<td>60</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>275-550</td>
<td>95.3</td>
<td>133</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;550</td>
<td>96.9</td>
<td>746</td>
<td>0.7</td>
</tr>
<tr>
<td>3</td>
<td>Residential area, no lead contamination</td>
<td>—</td>
<td>99.2</td>
<td>694</td>
<td>0.8</td>
</tr>
</tbody>
</table>

*Total score of components adjusted to a mean of 100 for the city as a whole
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The results given in Table II were altered very little by adjustments for social class, birthrank, and maternal age distributions. This is shown in Fig. 1 where mean scores, standardized jointly for social class, birthrank, and maternal age are given for each group. In addition to the final score, Fig. 1 also gives comparisons for each of the verbal reasoning scores (VR1 and VR2), the mathematics score, the English score, and the sum of these four components (total score). The adjusted mean scores were determined by the indirect method using all the children who took the selective examination in Birmingham during 1961-64 as the standard population. The vertical line given with each mean in Fig. 1 indicates 95% confidence bounds.

For each of the scores the same sort of pattern appears. There were clear differences between the scores of children attending schools in Area 1 as compared with those of children attending schools in the other two areas. The children in Area 1 scored consistently higher in each examination. On the other hand, no significant differences were found among the distance subgroups either in the high-lead or the low-lead area. The fact that the same pattern occurs for each of the separate score components is an indication of the consistency of the tests. They should not, however, be viewed as completely independent demonstrations of the same phenomenon; it is to be expected that the component scores would be highly correlated with each other.

Fig. 2 provides comparison of the adjusted mean final scores according to the sex of the child. Again the picture is much the same as before. It might be noted, however, that while girls always tend to score slightly higher than boys, this difference is most marked for the children living within 275 m of the battery factory.

<table>
<thead>
<tr>
<th>High lead area (metres from factory)</th>
<th>Low lead area (metres from factory)</th>
<th>Residential area</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;275 275-550 &gt;550 275-550 &gt;550</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Final score</th>
<th>Total score</th>
<th>VR1 score</th>
<th>VR2 score</th>
<th>Math score</th>
<th>English score</th>
</tr>
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<tbody>
<tr>
<td>110</td>
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<td>90</td>
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</tr>
</tbody>
</table>

*± two standard errors

Fig. 1. Mean 11+ scores*, adjusted for social class, birthrank, and maternal age.

**DISCUSSION**

The results show that 11-plus examination scores of children living in a lead-polluted community were in fact higher than those of children living in two socially similar but unpolluted communities (Table II). While this finding would support the contention that lead pollution to this degree did not produce an overall deficiency in school performance, it cannot finally rule out the possibility of such an effect.

The higher score in Area 1 persisted despite standardization for social class, birthrank, and maternal age and it probably reflects differences in the quality of education in the three areas. Differences such as these are well known and were anticipated when the investigation was designed. Indeed, the decision to investigate the
effects of distance from a reference point within two of the areas was based upon this anticipated difficulty.

In fact, children living within 275 m of the battery factory did not score significantly less than those living outside that radius. Again, however, this negative finding is not completely reliable for two chief reasons.

First, a rather substantive deficit in the mean 11-plus score would be necessary to attain a reasonable chance of demonstrating statistical significance. In fact, the deficit would have to be in the order of 8% to achieve 90% power with a statistical test at the 5% significance level. For such a dramatic reduction a large proportion of the children living close to the factory would have to have been seriously affected. Although our investigation effectively rules out so great an effect, it is not sensitive to smaller changes. For example, to detect a 5% deficit with 90% power we would require 130 children from the area within 275 m of the battery factory as compared with the 55 actually studied. The detection of a 2% deficit would require 810 children!

Secondly, the small deficit in final scores among children living within 275 m of the battery factory compared with children living further away was greater for boys than for girls. Since differences in play activities probably result in higher exposure for boys than for girls, this finding could possibly indicate a small toxic effect. However, the differences in scores according to distance from the battery factory were not statistically significant for either sex and no definite conclusions may be drawn from them.

In addition to the problem of small numbers other aspects in a study of this kind make the detection of small effects difficult. Comparisons of the intelligence of children living closest to a source of contamination with those living further away will be confounded by other factors—such as, social class—which change according to distance from an industrial site. The use of a ‘control’ community is difficult because such factors do not distribute in exactly the same way for two different communities. Statistical techniques for standardization provide a way of removing major influences of bias but cannot be expected to eliminate all extraneous variation such as, for example, differences between schools.

The results of this investigation indicate that lead pollution of the magnitude reported in Area I does not have a broad and devastating effect upon the mental capabilities of children in the community. On the other hand, it must be recognized that a moderate effect on a small segment of the population might have escaped detection. Such an effect, if it exists, might be detected only by studies employing more sensitive measures of individual exposure.

This investigation was carried out as part of a joint programme of work co-ordinated through the Scientific Advisory Committee on Environmental Pollution of the City of Birmingham. It was supported by a grant from the Birmingham City Council. Our thanks are due to Dr W. Nicol, and Mr J. Charlton for assistance and encouragement, and Mr E. N. Wakelin and Mr A. Archer for providing data on dust lead levels, and to Mrs Betty Mann and Miss Varsha Modi of the Department of Social Medicine and Health Services, Research Centre who helped to assemble the data.

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REFERENCES