THE EXPOSURE TO LEAD OF WORKERS IN THE PIGMENT INDUSTRY

F. HARTOGENSIS

Instituut voor Gezondheidstechniek TNO, Afdeling Industriële Luchtverontreiniging, 's Gravenhage, Nederland

INTRODUCTION

In order to obtain more data on the effect of inhalation plumbiferous dust by workers, a systematic examination was organized in a number of pigment factories in the Netherlands. Some experience had been gained from a former examination of an analogous nature held in factories where lead accumulators were manufactured. . Based on this examination, and after discussion in a committee on which several experts sat, a scheme for this examination was drawn up which may be divided in three parts:

(a) an environmental examination of the concentration of plumbiferous dust in the various factory departments, combined with an investigation of the measures designed to combat the pollution of air, such as encasing, exhausting and ventilation;

(b) a medical examination of all workmen, whether they have been exposed to plumbiferous dust or not;

(c) an analysis of the duties performed by each workman, the analysis being particularly detailed where the last few months were concerned.

Part (a) was carried out by the Department of Industrial Air Pollution, Research Institute for Public Health Engineering T.N.O., part (b) by the Department of Occupational Medicine of the Netherlands Institute for Preventive Medicine, part (c) by these two departments together. The Inspectorate of Factories and, in particular, the Medical Service of this Inspectorate, assisted in it. Industrial physicians were employed where possible.

Mr Zielhuis will report on part (b). The examination has, at the moment, only been completed in two factories; it will be continued in other similar factories. This report, which contains only those data which seem to be of importance for the determination of the maximum allowable concentration, should, therefore, be regarded as a provisional one.

THE DETERMINATION OF THE LEAD CONCENTRATION IN AIR

Air in the factory was sucked through a filter paper (Schleicher and Schüll, No. 589[3], " blue band ", 9 cm diameter) at a rate of 1·5–2 m^3/half-hour; as a rule each determination required 15 to 45 minutes. The volume of air sucked through was measured by means of a dry gas meter. The filters were

afterwards destroyed with a mixture of concentrated sulphuric acid, concentrated nitric acid and hydrogen peroxide; if necessary, lead sulphate is kept in solution by the addition of ammonium acetate. The lead was then extracted with a solution of dithizon in carbon tetrachloride and re-extracted with an aqueous solution of nitric acid; the greater part of the interfering ions being thus removed. After the addition of ammonium citrate, potassium cyanide and ammonia (to give a pH 8 to 9), a dithizon solution in carbon tetrachloride was added for the actual determination. qeel absorption of light of the organic layer at 620 mμ was measured, as well as the absorption of the layer after the lead had been extracted by shaking with dilute nitric acid. The difference between these two absorption values was equivalent to the lead concentration (reversion method). This mode of determination is sensitive (to less than 1μg of lead), reliable, and does not take too much time.

In the two factories together a total number of about 200 lead-determinations has been carried out in addition to over 50 determinations by means of the thermal precipitator. Moreover, the concentration of chromium in the filters has also been determined in most instances.

THE CONCENTRATION OF LEAD IN THE AIR

In one of the factories (factory *A*), the examination was carried out in July 1957, November 1957 and April 1958; in the other one (factory *B*), in January, February, March, and September 1958. In this way the influence of accidental circumstances was reduced as much as possible. There are positive indications that the concentrations may vary considerably in different months. During one series of measurements (in January 1958 in factory *B*) abnormally low concentrations were found which, for certain reasons, have not been considered further.

In one of the factories the manufacture of Prussian blue was carried out in a separate building, in the other one in a hall which was in free communication with other rooms, in which (among other things) lead chromate was milled. In the former factory no lead was found in the department in question. In the second case, the concentrations of lead found in that department were, as a rule, indeed low ($\simeq$ 0·04 mg lead/m^3 air), but on some occasions the concentrations were very high (0·60 and 0·84 mg lead/m^3 air). The explanation was not difficult to find. From a study of the movement of the air it appeared that an air stream was occasionally sucked into this department from other rooms. The average concentration is, however, difficult to determine; it is, after ample consideration, assigned a value of 0·10 mg lead/m^3 air.

In a department where white lead was manufactured by the wet method, but where no drying took place, the average concentration amounted to 0·03, and the highest concentration found amounted to 0·08 mg lead/m^3 air. During the manufacture of chrome yellow by the wet method in one of the factories, the average concentration in the room was only 0·01 mg lead/m^3 of air, except for one place where the chrome yellow from the drying-chambers was dumped into drums. On that site an average concentration of 0·08, and peak concentrations up to 8·2 mg lead/m^3 air were found. As it was known—at least approximately—how much time each of the workmen

spent dumping the material, an average exposure could be determined in this instance.

When chrome yellow and chrome green, consisting of lead chromate and a mixture of lead chromate and Prussian blue respectively, were milled, high concentrations were often found. As averages in the various rooms of these two factories we found 0·13–0·15–0·16–0·23–0·39–0·39–0·65 and even 1·43 mg lead/m³ air. Most of the high average concentrations were again found where the pigments were bagged: 0·08–0·35–0·91 and 1·28 mg lead/m³ air. In the stores, on the other hand, the concentrations were mostly low, averaging 0·08 and 0·10 mg lead/m³ air, although higher values up to 0·57 mg lead/m³ air were occasionally observed.

In several instances the determination of an average concentration from 5 to 10 determinations was possible only with a good deal of inaccuracy. For instance, in one room (where chrome green was milled) an average concentration of 0·23 mg lead/m³ air was found with a standard deviation from this average of 0·09. The cause of the wide variation in the results is not known to us. Where it is known a better estimate can sometimes be given. With an installation for milling chrome yellow, high to very high concentrations were constantly found when the mill was being cleaned. It was estimated that the mill was cleaned for half an hour after an operation of approximately five hours. During normal operation the average concentration amounted to 0·15 mg lead/m³ air, standard deviation 0·03; during cleaning 2·79 mg lead/m³ air, standard deviation 2·27 (!). Based on these data the average concentration amounted to

$$\frac{10 \times 0{\cdot}15 + 2{\cdot}79}{11} = 0{\cdot}39 \text{ mg lead/m}^3 \text{ air.}$$

It is apparent that these results are highly inaccurate; the standard deviation amounts to 0·23, but the ratio 10:1 is also rather inaccurate. Fortunately, most average concentrations are not so inaccurate.

ANALYSIS OF WORK

This turned out to be much more difficult than was expected. The factory management issued a list giving the names and ages as well as brief indications of the jobs of all workmen. In addition every workman was asked to state his former duties and to give a more detailed description of his duties during the last month. Many workmen appeared to perform various duties, sometimes with widely varying exposures, without being able to give an accurate account of the way in which they divided their time. Some workmen even failed to give us a clear picture of their duties. A fairly large group, that of the technical service, moved about the factory in an ever-changing manner. As the concentrations were measured at certain sites, and during certain operations, and as the medical examinations concerned only individuals, the relation between these two factors could be examined only if the exposure of each workman could be determined from data obtained. This was not possible, therefore, with every workman.

DIVISION INTO EXPOSURE GROUPS

In order to be able to continue the examination in the circumstances, a

division was made into exposure groups, which were at first defined as follows:

Group I: no lead exposure;

Group II: slight lead exposure; the average concentration to which these workmen were exposed being $<0{\cdot}15$ mg lead/m^3 air;

Group III: heavy lead exposure; the average exposure varying from 0·15 mg to 0·75 mg lead/m^3 air;

Group IV: very heavy lead exposure; the average concentration amounting to $>0{\cdot}75$ mg lead/m^3 air.

The workers were examined at the beginning of the investigation; the available data determined to what group they were to belong. Afterwards it appeared that for a number of workmen in factory *B*, who had been allocated to Group IV, the estimated exposure was too high; based on a large number of determinations, and on a better estimation of the duration of the various duties, the assessment of the exposure had to be lowered. In fact this set the limit between Group III and IV at $\doteq 0{\cdot}65$ instead of 0·75 mg/m^3. However, Group IV comprised only a small portion of the workmen, and the conclusions from the medical examination and from the examination under review were not affected by this change.

From the available data, the average inhaled concentrations has also been calculated for each of the 8 groups of workmen (4 groups in 2 factories). For that purpose a certain value was assigned to the average concentration found in the various operations, the value being proportional to the number of working men. This calculation is superfluous for group I, reasonably practicable for groups II and III, but less reliable for group IV, because as a rule widely varying concentrations were concerned, the peak values of which only occurred during a limited time, although they might have had a great influence on the average For the average exposure we estimated:

	Group I	Group II	Group III	Group IV
Factory *A*	0·00	0·10	0·21	1·2
Factory *B*	0·00	0·07	0·35	0·65

The workmen of the technical service, whose average exposure could not be determined, are also classed in group II; it is almost certain that their exposure will be $<0{\cdot}15$ mg/m^3. The data indicate that this group will most likely have a somewhat higher exposure in factory *A* than in factory B.

Finally, it should be observed that at least 80 per cent of the lead found in the air was present as chrome yellow, that is as $PbCrO_4$. The view sometimes held that this compound, which is almost insoluble in water, is less dangerous or not dangerous at all would appear, therefore, to be erroneous.