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Lead exposure during demolition of a steel structure coated with lead-based paints

I Environmental and biological monitoring

by Ton Spee, PhD,¹ and Willem CM Zwennis²

SPEE T, ZWENNIS WCM. Lead exposure during demolition of a steel structure coated with lead-based paints: I Environmental and biological monitoring. *Scand J Work Environ Health* 13 (1987) 52–55. Demolition of a steel railway bridge was carried out by nine workers using flame-torch cutting. The air in the breathing zone of the workers contained from 2 to 38 mg of lead/m³, which is a very high level in comparison with the Dutch exposure limit of 0.15 mg/m³ (8-h time-weighted average). Without very effective respiratory protection these concentrations may result in acute lead poisoning. Upwind of the flame-torch exposure the level was below the exposure limit, whereas downwind lead concentrations of up to ten times the exposure limit were observed. Although filtering facepieces were used by the workers, average blood lead concentrations of about 4.5 µmol/l were rapidly attained. Possibly under these work conditions this value represents a maximum concentration attainable in blood. After termination of the exposure, there was a fast decrease of lead in the blood. This finding indicates that lead was mainly present in rapidly exchangeable compartments like blood. No stable correlation between the concentration of lead in blood and the concentration of zinc protoporphyrin in blood was found.

Key terms: industrial hygiene, occupational hygiene, zinc protoporphyrin.

Although it is known that the flame cutting of lead-painted steel constructions may cause severe lead poisoning (5, 6, 10), exposure to lead fumes during this type of work still occurs. Such exposure may be due to the fact that the workers are insufficiently aware of the risk involved or the fact that the respiratory protection of the workers may be insufficient or may turn out to be difficult in practice.

The Dutch Labour Inspectorate has requested the Medical Biological Laboratory TNO to monitor lead exposure of workers involved in the demolition of a railway bridge. At the same time the health effects due to exposure to lead were studied through measurements of the delay and repair of nerve conduction velocity in the workers (8).

The arched steel railway bridge, built in 1902, consisted of two fixed bridges and a swivel bridge. Its total length was 265 m and the maximum height of the arches amounted to about 11.5 m. The bridge had been painted seven times with a 0.1-mm coating of a primer containing 60 % lead and with a 0.02-mm top coat containing green chromium oxide. The bridge was taken down during the period October 1983 through February 1984 by flame-torch cutting (oxypropane flame). Seven workers cut on the bridge, and two cut parts to smaller pieces. One of the latter worked mainly on

a deck ship, the other mainly on the bank of the canal.

Several authors have reported on the relationship between the concentration of lead in the breathing zone (PbA) and that in the blood (PbB) of occupationally exposed workers. According to Alessio & Foa (1) and Coenen & Drasche (3) there is a linear relationship in groups of workers for PbA up to 0.2 mg/m³. However, on an individual basis the PbB concentration cannot be derived from PbA concentration (7). Unpublished investigations by us in three lead-battery factories support the latter observation.

Subjects and methods

Air sampling

Air was sampled from the breathing zone by pumping air through a stainless steel filter holder fixed to the lapel of the worker (personal air sampling). The holder, with an opening 7 mm in diameter, contained a cellulose nitrate membrane filter and was connected to an air sampling pump (Du Pont P 2500) by Tygon tubing. The flow rate was 2 dm³/min. With this equipment particles with an aerodynamic diameter up to 30 µm are sampled. This method meets the criteria specified in the directive on inorganic lead issued by the Council of the European Communities (CEC) (4).

Large samples were taken by means of portable high-volume samplers (Portikon, Sartorius) at a flow rate of 200 dm³/min.

The lead concentrations were determined by atomic absorption spectrophotometric analysis (Varian Tech-

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iron AA 9751) after the filters were dissolved in aqua regia. The measurements were performed during dry weather and wind velocities of 1–2 m/s.

Analysis of lead and zinc protoporphyrin in blood

Venous blood was collected in 5-ml lead free tubes containing 7.5 mg of ethylenediaminetetraacetate-disodium salt (EDTA-2Na) (Venoject, Terumo). The PbB concentration was determined (12) after the addition of 100 μ l of blood to 900 μ l of 1 M nitric acid and swirling. The precipitate was centrifuged, and lead was determined in the clear supernatant by atomic absorption spectrophotometric analysis (Perkin Elmer model 4000, HGA model 500). The day-to-day coefficient of variation of the method was 7 % at 2.07 μ mol/l and 6 % at 3.75 μ mol/l ($N = 17$).

The concentration of zinc protoporphyrin (ZPP) was determined with a direct-reading hematofluorometer (Environmental Sciences Association, model 4000) after oxygenation of a 100- μ l blood sample by swirling on a shaker.

Results

Environmental monitoring

Table 1 shows the concentration of lead in the breathing zone of the workers for three periods on the same day 13 weeks after the start of the demolition. Workers 1 to 4 were engaged in flame cutting on the bridge. Worker 5 was cutting demolished parts of the bridge into smaller pieces on a deck ship.

Air samples were taken upwind and downwind of the torch simultaneously. The results are shown in table 2.

Biological monitoring

The PbB and ZPP concentrations were determined in blood collected before the work started (between weeks 0 and 2), four times during the demolition (weeks 7–20) and two times after the job was finished (weeks 39 or 40 and week 89). Due to absence some workers did not participate in the sampling on every occasion. The results are presented in table 3 (PbB) and figure 1 (ZPP).

Discussion

During the first three months of the job the respiratory tract of the workers was protected by filtering facepieces. Thereafter half-mask respirators in combination with dust filters, class P2, were available. The results of the environmental monitoring show that concentrations of 30 times the Dutch exposure limit for lead (0.15 mg/m³, time-weighted average over 8 h) were not exceptional. Other authors have also observed

Table 1. Lead concentrations in the breathing zone of five workers (personal air sampling) during the demolition of a lead-painted steel structure (20 January 1984).

Worker	Lead concentration (mg/m ³)		
	Period 1 (0800-0945)	Period 2 (1015-1230)	Period 3 (1315-1445)
1	10.8	.. ^a	.. ^a
2	32.3	17.3	5.7
3	20.5	2.3	3.2
4	38.1	13.4	6.0
5	3.1	3.3	3.7

^a Measurement not successful.

Table 2. Results of simultaneous sampling upwind and downwind at a distance of 50 cm from the flame torch. The sampling was performed during period 2 by means of portable high-volume samplers (20 January 1984).^a

Worker	Sampling time (min)	Lead concentration (mg/m ³)	
		Upwind	Downwind
1	7	0.08	1.7
2	14	0.06	14.0

^a In order to avoid disturbing effects, only worker was at work during the sampling.

Table 3. Blood lead concentration (μ mol/l) of the workers during demolition of a railway bridge.

Worker	Week						
	0 or 2	7 or 8	11 ^a	14 or 15	20 ^b	39 or 40	89
1	1.7	4.5	5.1	4.2	5.0	2.6	1.3
2	2.3	..	..	2.7	4.5	3.0	1.5
3	1.9	4.9	5.5	4.2	4.3	2.4	1.4
4	1.3	3.8	4.5	3.8	4.2	2.4	1.1
5	2.5	5.3	5.4	4.7	5.0	3.0	2.7
6	1.9	4.5	3.8	3.3	..	2.1	1.2
7	1.6	3.3	4.4	3.4	3.2	2.3	1.3
8	1.2	4.8	4.3	3.8	..	1.8	..
9	..	3.7	3.1	2.4	2.5	1.6	0.7
Mean	1.80	4.35	4.51	3.61	4.08	2.36	1.40
SD	0.45	0.68	0.82	0.74	0.94	0.49	0.57

^a Season holidays during week 12.

^b The work was completed shortly after week 20.

high exposure during flame-torch cutting in open air (5, 11). Even with protection by a half-mask respirator the situation was unacceptable, since, for this type of mask, a protection factor of only 10 to 12 is specified (2, 9). The high exposure of workers 2 and 4 compared to that of workers 1 and 3 may not only have been due to exposure to lead fumes produced by themselves, but also to those produced by their colleagues. Workers 2 and 4 worked downwind of workers 1 and 3 at a distance of about 10 m.

It is often stated that, if a worker stays upwind of the torch, the exposure to lead fumes should remain at an acceptable level. To determine the validity of this statement, we took simultaneous air samples at a distance of 50 cm upwind and downwind of the torch. The results in table 2 indicate that indeed upwind the exposure is below the exposure limit, the more so be-

Figure 1. Zinc protoporphyrin concentration in the blood of the workers (marked by the numbers in the figure) during demolition of the railway bridge. (The worker numbers correspond with those in the tables.)

cause usually the distance between the worker and the torch is about 1 m. However, when working on a 30-cm broad bar, 10 m above ground level, a worker is not always able to take the right position with respect to the wind.

All workers had raised PbB levels (normal value $< 1 \mu\text{mol/l}$) and most of them also had raised ZPP levels (normal value $< 65 \mu\text{mol/mol Hb}$) before the work started, and therefore they had evidently been exposed to lead previously. However, during the first weeks of the demolition of the bridge the PbB concentration increased sharply to $3.5\text{--}5.5 \mu\text{mol/l}$.

Shortly after the collection of the blood samples in week 11, the work was interrupted for a week of sea-season holidays. After resumption of the work half-mask respirators in combination with a dust filter, class P 2, were available to the workers instead of the filtering facepieces used during the preceding period. The average PbB decreased significantly. (Compare weeks 14/15 to week 11; $\alpha = 0.05$, multiple comparison analysis according to Friedman). This finding indicates that the use of the masks resulted in a diminished uptake of lead. Nevertheless the average PbB was still above the limit value of $2.9 \mu\text{mol/l}$ and therefore suggested that the protection provided by the half masks was also insufficient. (See reference 11.) However, notwithstanding an exposure that notably exceeded the exposure limit, the average PbB did not exceed $4.5 \mu\text{mol/l}$. Apparently, at this level, a plateau is reached where a dynamic equilibrium exists between uptake, storage in depots, and excretion. Such a plateau could explain

why worker 5, whose exposure was much lower than that of workers 1–4, showed a similar PbB during weeks 7/8 through 20. No linear relation was found between PbB and PbA.

After the job was finished (week 20) the PbB level decreased, the average concentration in week 89 differing significantly from that in weeks 0 or 2 (t-test for pairs, $P_2 = 0.022$). Apparently exposure between weeks 20 and 89 was less than during the period preceding the demolition. Usually the workers followed by us are involved in other types of demolition work, demolition of steel constructions being only a minor fraction.

The PbB values in weeks 0 or 2 show that, during the preceding period, exposure to lead was relatively low compared to the exposure during demolition. Other compartments, therefore, played only a minor part in the decrement of PbB. While in week 11 the average PbB reached its maximum, the ZPP concentration was still increasing. Since ZPP is formed in the bone marrow and the life-span of erythrocytes is about 120 d, the exchange of the entire population of erythrocytes requires that length of time. Therefore, at the end of the work in week 20, the concentration of ZPP was still in an increasing phase. The CEC directive on inorganic lead (4) states a limit value of $3.4 \mu\text{mol/l}$ for PbB but a concentration between 3.4 and $3.9 \mu\text{mol/l}$ is acceptable if the ZPP concentration is lower than $500 \mu\text{mol/mol Hb}$. With the exception of the value of worker 9, the PbB level of all the workers exceeded the first criterion at one or more times.

Concluding remarks

The demolition, by flame-torch cutting, of a steel structure coated with lead-based paints resulted in very high concentrations of lead in the breathing zone of the workers. Without the use of effective respiratory protection such concentrations may result in acute lead poisoning.

Exposure to high concentrations of lead resulted in a fast increase of the concentration of PbB. After the exposure was terminated, there was a fast decrease in the PbB values that indicated that the body burden of lead was mainly present in rapidly exchangeable compartments.

The use of half-mask respirators during the work resulted in significantly lower PbB concentrations. In addition working in a position upwind of the torch also provided a substantially lower exposure to lead.

Exposure to PbA concentrations ranging from 3 to 30 mg/m³ resulted in average PbB concentrations of about 4.5 µmol/l. This finding might indicate that this value represents an equilibrium concentration attainable in blood under the conditions given.

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