

# Absorption and Excretion of Mercury in Miners

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STUDIES have been conducted in an attempt to determine the existence of correlations between environmental levels of mercury in mines and smelters and levels in blood and urine of mine employees. Data were obtained in mines and smelters at Idrija, Yugoslavia, and Palawan Island in the Philippines.

## Idrija

The mercury mines of Idrija, Yugoslavia, are of considerable antiquity, having been opened in the fifteenth century. The clinical picture of mercury poisoning in the miners employed there was described by Paracelsus and subsequent authors.<sup>1,2</sup> A number of reports dealing with various health aspects at Idrija have appeared since World War II. Hribernik<sup>3</sup> listed in detail the clinical patterns of mercury poisoning occurring at Idrija, pointing out that the acute form was not seen, but rather the subacute, chronic, and chronic-stationary syndromes. None of these is sharply demarcated and each tends to overlap the others. Erethism was commonly found in patients with a recurrence of a previous subacute episode. Vouk *et al.*<sup>4</sup> described the mining operation and did extensive air studies in 1950, reporting a range of 0.05–5.9 mg./cu.m. in the mine and 0.17–1.1 mg./cu.m. in the smelter. Njemirovski<sup>5</sup> noted the

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prevalence of inflammation of the oral cavity as 36% in miners and 34% in smelter workers. He did not present any data on a comparable population with no occupational exposure. Krajina<sup>6</sup> performed audiometric and caloric studies on a group of 83 miners and smelter workers and found the results to be within normal limits in the healthy workers and in those suffering from subacute poisoning. Mild hearing losses in the higher frequencies were found in those suffering from chronic poisoning. A higher percentage of lesions was found in the older workers. The caloric tests yielded irregular results in 50–60% of the cases, suggesting heightened reaction. Kesic *et al.*<sup>7</sup> conducted hematological investigations on 189 miners at Idrija, 71 of whom had pronounced symptoms of chronic mercury poisoning, and found no significant abnormalities in the blood picture as compared with that in controls.

The present study was undertaken in an attempt to gain some idea of the possible correlation of mercury in blood and urine with the environmental levels found simultaneously in the mine and smelter. A number of the recommendations proposed by Hribernik and Vouk such as improved ventilation and the rotation of workers have been put into effect. Perhaps as a result of this, relatively few cases of mercury poisoning were seen by us and the signs and symptoms of intoxication they presented were generally mild.

It was not possible in most instances to relate the air levels of mercury at different locations to individual exposures, as the miners do not remain constantly at one location but rotate through different positions in the mine. The ranges of exposure levels, however, are shown in Table I. It can be seen that the total mercury concentrations in the mine ranged from 0.16 to

4.89 mg./cu.m. and the mercury vapor concentration from 0.1 to 2.0 mg./cu.m., with 0-2.0 mg./cu.m. in the smelter.

A total of 74 male employees was examined, including representative groups from different occupations in the operation. One group of 10 had worked at different periods in the smelter and in the mine. The maintenance workers—including mechanics, carpenters, and storekeepers—had no ostensible mercury exposure, but the environmental mercury levels in the

food and water at Idrija are not known. Further studies on this aspect are in progress. Undoubtedly, exposure from working on mercury-contaminated equipment used in the mine or smelter was present.

The blood and urine mercury results (determined by the method of Jacobs<sup>8</sup>) in 58 workers with no definite symptoms or signs of mercury poisoning are shown in Table 2. The symptomatic cases listed in Table 3 had some combination of the rather protean manifesta-

TABLE 1. AIR MERCURY CONCENTRATIONS IN THE IDRIJA MINE  
(MAY 30-JUNE 1, 1963) AND SMELTER (MAY 31, 1963)

Location	Position	Concentrations (mg.Hg/cu.m.)	
		By Unijet sampler*	By mercury vapor meter
MINE			
I/15	At work station 2 m. distant		1.10 0.70
I/15-48	At work station 10 m. distant	2.22	1.50-1.60 0.90
I/9-invest.	At work station A 6 m. distant In corridor	3.66	0.95-1.50 0.70 0.70-0.80
I main-invest.	At work station B At work station C At work station 4 m. distant In main corridor	3.57 2.38	1.25 1.60 2.00 1.60-1.70
I main corridor	Transportation Corridor A Corridor B	0.42 0.36	0.22 0.24
II/28		0.46	0.20
II/29		4.89	2.00
II/10			1.20
II/Kropac		0.33	0.18
II/Kropac 4		0.46	0.20
VI/1	At work station 4 m. distant	0.18 0.16	0.10 0.10
VII/2	During drilling	1.56; 0.89 0.66	0.40 0.25-0.40
SMELTER			
Pressing-out dept.†	In center of room In vicinity of presses		1.40 2.00
Bottling and weighing dept.	Bottling Weighing		1.50 0.40
Below condenser of rotary furnace			0.00-1.00‡
Spirek furnace	Not loading (upper level) Loading (lower level)		0.10 0.50-1.50

\*Union Industrial Equipment Corp., Port Chester, N. Y.

†With no assisted ventilation.

‡Dependent on wind direction.

tions of mercury poisoning such as sleeping poorly with jerking during sleep, irritability, personality change, salivation, tremor, gingivitis, and tremulous handwriting.

Comparison of the blood and urine mercury levels of all the workers examined is significant at the 2% level using the nonparametric Spearman rank correlation coefficient—that is, high blood values are usually associated with high urine values and vice versa. This cannot be considered as applying to an individual case. The average urine and blood mercury levels of the different work categories and symptomatic subjects do not vary markedly and, as the ranges of values are so great and the number of workers in each group small, it would be fruitless to compare the groups with the expectation of arriving at any valid conclusions.

The matter is further complicated in that a

number of the symptomatic subjects had been off work for rather long periods. Oikawa, in reporting on miners,<sup>9</sup> and Markwith, who dealt with workers in copper mercury amalgam,<sup>10</sup> followed the urinary mercury excretion of several workers after their occupational exposure had been stopped. They found, as a group, that the urinary mercury levels drop by about 37–47% in one month and 68–84% in 2–3 months. However, the individual variation around these percentages fluctuated widely. Extrapolation from these data leads to the assumption that, in Cases 1–4 and 12, urinary mercury levels might have been considerably higher at the onset of the illness. This speculation is of interest particularly concerning the subject of Case I, who presented the most severe clinical picture.

In Cases 7, 8, and 11, in which there had been a prior history of mercury poisoning, all subjects

TABLE 2. MERCURY LEVELS IN ASYMPTOMATIC IDRIJA WORKERS

Activity	No. of workers	Blood ( $\mu\text{g./100 ml.}$ )		No. of workers	Urine ( $\mu\text{g./L.}$ )	
		Range	Av.		Range	Av.
Mining	17	0–30.6	6.6	17	0–1275	329
Transportation in mine	6	0–14.4	4.3	6	14– 560	317
Smelting	8	0–32.0	9.7	8	92– 713	279
Smelting-mining	10	0–21.0	9.7	10	0–1020	279
Maintenance	16	0–45.0	7.9	17	0–1012	205
TOTAL	57	0–45.0	7.7	58	0–1275	276

TABLE 3. MERCURY LEVELS IN IDRIJA WORKERS WITH SYMPTOMS OF MERCURY POISONING

Case No.	Age (yr.)	Time on job (yr.)	Job	Days absent prior to examination	Year of previous Hg poisoning	Hg level	
						Blood ( $\mu\text{g./100 ml.}$ )	Urine ( $\mu\text{g./L.}$ )
1	43	13.0	Miner	91		5.4	396
2	27	10.0	Miner	34		3.9	256
3	24	1.0	Miner	29		11.4	196
4	43	11.0	Miner	25		0.0	601
5	48	16.0	Miner	12		2.1	264
6	35	12.5	Miner	12		1.5	33
7	43	15.0	Miner	4	1950	0.5	2
8	34	16.0	Miner	4	1948	0.0	27
9	34	5.0	Miner	4		—	396
10	37	11.0	Miner	4		36.9	597
11	47	13.0	Miner	2	1959	0.75	12
12	41	8.0	Smelter	90		48.0	272
13	33	5.0	Smelter	59*		51.0	203
14	36	15.0	Smelter	4		4.0	100
15	34	7.0	Smelter	4		2.1	220
16	20	5.0	Smelter	2		0.0	504
RANGE						0–51.0	2.0–601
AVERAGE						11.2	255

\*Then returned to work 12 days.

TABLE 4. MERCURY LEVELS IN PALAWAN WORKERS

	No. of workers	Blood ( $\mu\text{g./100 ml.}$ )		No. of workers	Urine ( $\mu\text{g./L.}$ )	
		Range	Ave.		Range	Ave.
1962						
Symptomatic	17	0.6-24.9	8.2	15	10-1305	277.4
1964						
Symptomatic	15	0.6-24.0	10.3	15	3-1260	389.0
Asymptomatic	15	0.9-30.0	13.5	15	75-2175	652.0

had low levels of mercury in the blood and urine—an interesting point, in view of Hribernik's observation that those with recurrence of subacute poisoning frequently show erethism. Perhaps the symptoms are triggered by a relatively low exposure.

In Case 12 the subject was recovering from optic neuritis, and the visual fields were still grossly constricted when examined by the confrontation test. Involvement of the optic nerve in exposure to alkyl mercurials has been described by several investigators.<sup>11-16</sup>

In a perimetric examination of 517 workers at the Almaden mines Perales and Aguirre<sup>17</sup> found 3 cases of scotoma which they ascribed to the effect of mercury. It is, of course, impossible to implicate mercury categorically as the cause of the disease in Case 12, in which exposure was limited to inorganic and metallic mercury. The blood mercury level in this case is puzzling considering the subject's long absence from occupational exposure.

## Palawan

The mercury mine on Palawan Island in the Philippines, an open pit operation developed since World War II, is much smaller than that at Idrija, employing less than 100 men. In 1962 a study was made of 17 workers there who had varying combinations of mild symptoms of mercurialism such as tremor, gingivitis, irritability, and salivation. Since it was impossible to do air studies as extensive as those done at Idrija, the Kitagawa mercury vapor detector tubes were used and showed a range of 0.1- $>2.0$  mg./cu.m. The single value above 2.0 mg./cu.m. was found at one kiln. This method does not measure the mercury present as cinnabar dust, which at times may be present in high concentrations.

In 1964 another survey of the Palawan mine was done during which 30 employees were ex-

amined, all of whom were working. Fifteen denied any symptoms and the remainder had various symptoms and signs suggestive of mercury poisoning but, in general, to a much milder degree than was found in the symptomatic Idrija workers. Mercury vapor in air (Table 5), again determined by the Kitagawa method at different locations in the mine and smelter, ranged from 0.0- $>2.0$  mg./cu.m., with two kilns showing the only readings greater than 2.0 mg./cu.m. The results of the blood and urine mercury determinations, similar to those found at Idrija, are listed in Table 4. (Two urine samples were lost to use in transit.) The differences between the 1964 symptomatic and asymptomatic groups are not statistically significant. A cultural factor that may increase the ingestion and skin absorption of mercury in these men is the firmly held belief that bathing immediately after work is the cause of tremor. Eight men who were examined both years had mild symptoms of mercurialism in 1962, but only 4 had symptoms in 1964. The fluctuations in results from one run to the other in all 8 were too great to permit any valid conclusions to be drawn from these data.

TABLE 5. MERCURY VAPOR (MG./CU.M.) IN AIR  
(BY KITAGAWA DETECTOR TUBE) AT KILN  
FEEDER AREA

Year	Kiln 1	Kiln 2	Kiln 3
1962	0.8	$>2.0$	1.2
1964	$>2.0$	1.0	$>2.0$

TABLE 6. MERCURY LEVELS IN PALAWAN FEEDERMEN

Year	No. of workers	Blood ( $\mu\text{g./100 ml.}$ )		Urine ( $\mu\text{g./L.}$ )	
		Range	Ave.	Range	Ave.
1962	4	3.9-19.5	9.1	75-277	153
1964	7	8.7-27.3	19.6	87-1013	678

Although few in number, the feedermen working at the ends of the kilns where the ore is steadily fed in for smelting, show results well related to the air mercury levels found each year at these work areas. The higher values for mercury in 1964 are reflected in higher blood and urine levels in the workers, as shown in Table 6. The differences between the 2 years are statistically significant at the 0.05 level. The maximum reading on the Kitagawa detector tube is 2.0 mg./cu.m.; thus, the highest exposure levels are not known. All four workers in 1962, but only 3 of those examined in 1964, had mild symptoms of poisoning. Two men were in the symptomatic group both years. The results with the 1962 group more nearly parallel the findings in the smelter workers at Idrija, where comparable work was done.

### Summary

Seventy-four male workers in the Idrija mercury operations were examined and the blood and urinary mercury levels determined. The ranges and averages of those with and those without clinical evidence of mercury poisoning did not demonstrate any remarkable difference.

Three symptomatic subjects with a prior history of mercury poisoning had low levels of mercury.

One case of optic neuritis was seen. It is impossible to determine if this was due to inorganic and metallic mercury.

Seventeen workers in a mercury mine in the Philippines with mild symptoms of poisoning and air exposure similar to that at Idrija showed blood and urine mercury content analogous to that found in the Idrija workers.

Two years later a second study was done at the Philippines mine encompassing 30 workers. A comparison of workers at the smelter area achieved higher blood and urine mercury levels than found in the earlier study, reflecting the higher mercury vapor concentration in air, but this does not appear to be related to production

of symptoms of poisoning. No increase in symptoms of mercurialism was found.

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### References

1. ROSEN, G. *The History of Miners' Diseases*. Schuman's, New York, 1943.
2. TELEKY, L. *Die Gewerbliche Vergiftung*. Springer, Berlin, 1955.
3. HRIBERNIK, I. Observations on occupational mercury poisoning in the mines of Idrija (1946-1950). *Arch Hyg Rad* 1:291, 1950.
4. VOJK, V. B., FUGAS, M., and TOPOLNIK, Z. Environmental conditions in the mercury mines of Idrija. *Brit J Industr Med* 7:168, 1950.
5. NJEMIROVSKI, Z. Oral manifestations in occupational mercury poisoning. *Arch Hig Rad* 3:436, 1952.
6. KRAJINA, Z. Lesions of the acoustic and vestibular apparatus in workers suffering from mercury poisoning. *Arch Hig Rad* 4:529, 1953.
7. KESIC, B., HÄUSLER, V., PUREC, L., and VANDEKAR, M. The influence of mercury vapor on blood elements and hemoglobin. *Arch Industr Health* 13:602, 1956.
8. JACOBS, M. B., GOLDWATER, L. J., and GILBERT, H. Ultramicrodetermination of mercury in blood. *Amer Industr Hyg Ass J* 21:276, 1961.
9. OIKAWA, F. A study on occupational mercury poisoning. *J Sci Labour* 31:82, 1955.
10. MARKWITH, R. H. Industrial mercurialism. Report of an investigation. Ohio Dept. of Health, 1940 (Processed).
11. HUNTER, D., BOMFORD, R. R., and RUSSELL, D. S. Poisoning by methyl mercury compounds. *Quart J Med* 9:193, 1940.
12. AHLMARK, A. Poisoning by methyl mercury compounds. *Brit J Industr Med* 5:117, 1948.
13. AHLBORG, G., and AHLMARK, A. The clinical features of intoxication from alkyl mercury compounds and risks of exposure. *Nord Med* 41:503, 1949.
14. HERNER, T. Poisoning from organic compounds of mercury. *Nord Med* 26:833, 1945.
15. LUNDGREN, K. D., and SWENSSON, A. Alkyl mercury compounds as a source of occupational disease. *Nord Hyg T* 29:1, 1948.
16. HÖÖK, O., LUNDGREN, K. D., and SWENSSON, A. On alkyl mercury poisoning. *Acta Med Scand* 150:131, 1954.
17. PERALES, N., and AGUIRRE, M. Las Alteraciones del Campo visual en Oberos de Mercurio. *Med Segur Trab* 2:9, 1953.

### VOLUNTARY HEALTH CHECKS

Do employees respond to voluntary health checks? The first week of the experimental new diabetes test (IRN—Aug. 7 '65, p. 2) at Goodyear Tire & Rubber Co., Akron, O., saw more than 96% of those employees scheduled taking the test.

*Industrial Relations News*, p. 4, Sept. 4, 1964.