

# Outbreak of Chronic Arsenic Poisoning among Retired Workers from an Arsenic Mine in Japan

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Retired former workers of Matsuo Arsenic Mine of Miyazaki prefecture in Japan were subjected to extensive medical examination. The number of retired workers subjected to examination were 61 of 208 workers who were engaged in the works of the mine and were tracked down by the work rolls. These workers left the mine more than 15 years prior to the time of the examination. The main works in the mine were classified as mining, dressing of ores, refining, and clerical work. Several findings such as arsenodermatitis, depigmentation, perforation of nasal septum, hyposmia, anosmia, and peripheral nervous disturbance attributed to exposure to arsenic were observed in 9 of 21 roasters who often worked in the arsenic kitchen. No characteristic findings of arsenic poisoning, that is, gastrointestinal disturbance, disorder of the cardiovascular system, hematopoietic disorders, or liver disturbance were observed in the retired workers. Another notable finding was that 8 cases diagnosed as pneumoconiosis were found in 18 miners.

## Introduction

In Japan, many cases of chronic arsenic poisoning have been observed, not only in the retired employee of metal mines or refineries but also among inhabitants of the surrounding countryside near closed mines and refineries. [Toroku-Kogai (1, 2) Matsuo-Kogai, and Sasagadani-Kogai (3)].

Matsuo mine is located in a mountainous district of Miyazaki prefecture (Fig. 1) and produced arsenic ore (arsenopyrite,  $\text{FeS}_2\text{FeAs}_2$ ) and other ores containing small amounts of gold, silver and antimony. At the height of prosperity of the mine, about 40 years ago, 85 workers were working at the mine which had ten kitchens and three roasters, and produced 25 tons/month of arsenic trioxide ( $\text{As}_2\text{O}_3$ ). The operation of the mine was started in 1934 and continued until 1958, even though there was temporary interruption of the operation during the period. The scale of the mine, roaster, and arsenic

kitchen was not large. Moreover, the environment of the work place was not well controlled and the workers must have been exposed to arsenic compounds, especially to  $\text{As}_2\text{O}_3$  in roasting and kitchen work.

A few investigations were made of the late effects of arsenic poisoning on the mine workers who left more than 10 years ago. In Japan, however, in the midst of increasing national concern on the late effects of arsenic poisoning, precise examination of arsenic poisoning is required from the viewpoint of industrial hygiene and environmental pollution caused by closed metal mines or refineries. At the Matsuo mine, 208 workers were detected by the rolls; they were employed during the operation between 1934 and 1958. Of these workers, 19 workers had already died by April 1972; the whereabouts of 141 workers were ascertained, and 61 of these 141 underwent physical examination.

## Methods

In view of few reports on arsenic poisoning in retired arsenic mine workers, examination items

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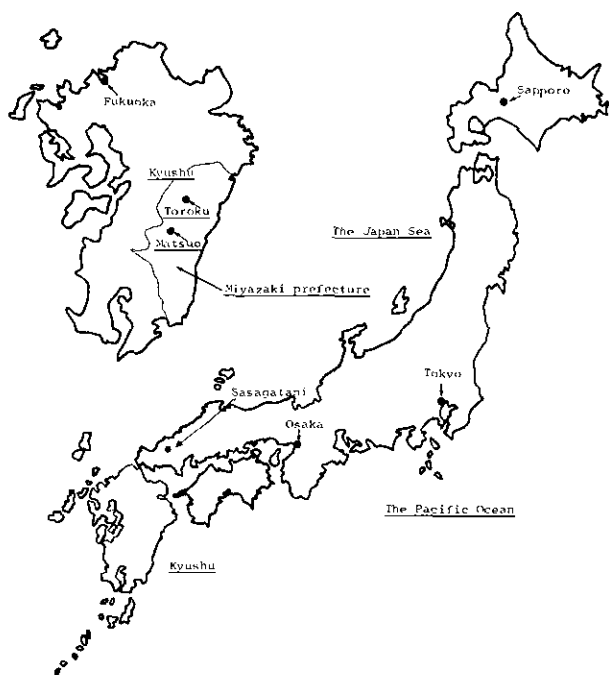


FIGURE 1. Location of Matsuo Mine.

were carefully selected by reference to the symptoms and signs of occupational chronic arsenic poisoning. In the examination, the effects on health of other metals present in the slag were also checked. The concentrations of metals contained in the slag are summarized in Table 1.

Table 1. Concentration of arsenic and metals in slag of closed Matsuo mine.

	As, ppm	Cd, ppm	Pb, ppm	Zn, ppm	Cu, ppm
Tailing	4030	2.3	89	69.2	71.2
Slag	38500	33.2	1690	803.0	298.0

The medical examination of the 61 retired workers from the Matsuo mine involved the following items: (1) history of symptoms of arsenic poisoning in their working period; (2) history of symptoms of chronic bronchitis and pneumoconiosis; (3) physical examination by doctors (dermatologist, general

physician, otorhinolaryngologist, and ophthalmologist; (4) examination of the cardiovascular system (ECG, blood pressure); (5) examination of the lungs and upper air-way, x-ray examination of chest, spirometric examination, and sputum examination; (6) blood examination (whole blood density, hemoglobin, hematocrit, erythrocyte and leucocyte counts, amount of serum protein); (7) urine analysis (pH, quantitative analysis of glucose, protein, erythrocyte, urobilinogen, and coproporphyllin); (8) biochemical and enzymological serum examination by SMA-12 (Technicon Co.); (9) determination of lead in whole blood by spectrophotometry; (10) determination of arsenic in urine and hair by atomic absorption method after reducing to  $AsH_3$ .

## Results

The workers were classified into four groups according to their function in the mine, that is, miner, ore dresser, roaster or smelter (arsenic kitchen worker), and clerical worker. The workers were distributed among the four groups according to age, period of service in the mine, and sex as shown in Table 2. In their working period, the chief complaints of arsenic kitchen workers were eruption with arsenical itch on the face, body and limbs, irritation of the upper airway, heartburn, and anorexia (Table 3). It was considered that these symptoms of arsenic kitchen workers were probably due to the heavy exposure to arsenic compounds under uncontrolled working environment. In the medical examination made 15 years after the exposure, however, they did not show hematopoietic disturbance, gastrointestinal disturbance, disorders of the cardiovascular system or liver characteristic of arsenic poisoning. The concentrations of arsenic in the urine and hair and of lead in whole blood of all retired workers were also determined found to be distributed in the normal range as shown in Figure 2. There were no remarkable differences in arsenic concentration of urine and hair or lead concentration in whole blood among the retired workers. However, of 21 roasters who often worked in the arsenic kitchen, nine were diagnosed showing evi-

Table 2. Classification of the workers receiving physical examination.

	Period of service, yr					Age*					Sex	
	<1	1-2	3-4	5-9	>10	35-40	41-50	51-60	61-70	70	Male	Female
Miner	1	4	4	8	1	5	6	3	2	2	18	0
Ore dresser	0	5	7	4	0	5	8	1	2	0	0	16
Smelter	0	2	9	6	4	4	4	9	3	1	18	3
Clerical worker	0	2	2	2	0	1	2	2	1	0	5	1
Total	1	13	22	20	5	15	20	15	8	3	41	20

\*Age at the time of the examination (1972).

**Table 3. Subjective symptoms of workers during the period of employment at the mine.**

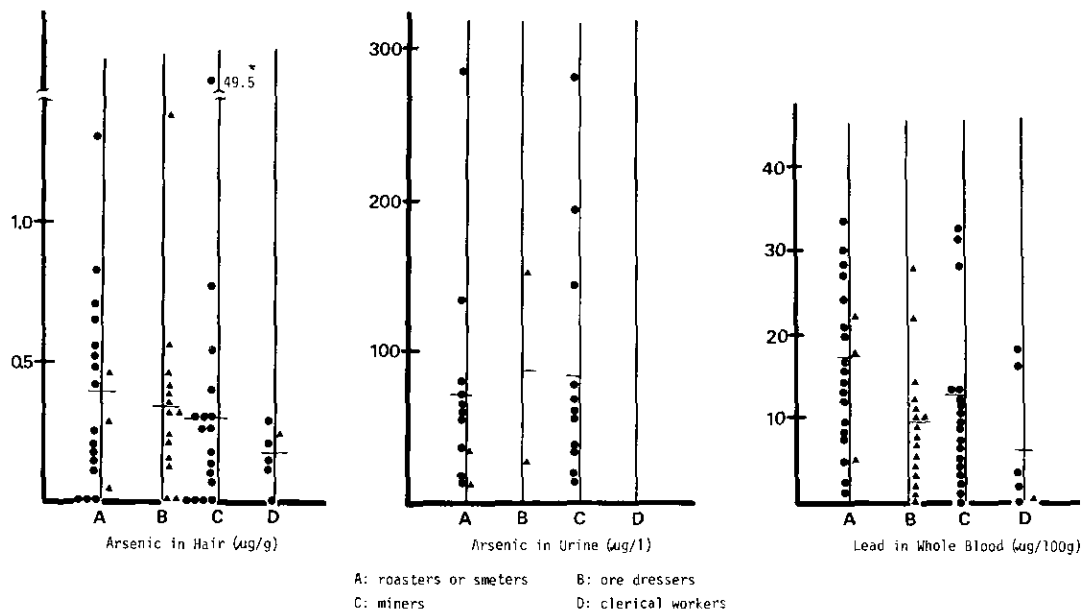
Work category	Sex	No. of Cases	Skin and	Gastro-	Respi-
			mucous mem-brane, %	intestinal tract, %	ratory organs, %
Smelter	F	18	38.9 <sup>a</sup>	18.9	60.2 <sup>a</sup>
Miner	M	18	18.9	23.3	34.3
Arsenic poisoning	M,F	11	54.6 <sup>a</sup>	27.3	72.7 <sup>a</sup>
Pneumoconiosis	F	8	18.8	25.0	36.4

<sup>a</sup> $p < 0.001$ .

<sup>b</sup>M = 9, F = 2.

nervous disturbance and motor paralysis. These cases showed a diminishing of tactile sensation, with numbness of extremities and a "pins and needles" sensation, and showed not only polyneuropathy but also unilateral multineuropathy without any motor paralysis. Of 21 roasters, another two cases seemed to be affected by chronic bronchitis, and the incidence of the disease might be related to the exposure to arsenic in the kitchen work.

In the miner's group, eight of 18 workers were diagnosed as having pneumoconiosis and they were



**FIGURE 2.** Concentrations of arsenic in hair and urine and of lead in whole blood: (A) roasters or smelters; (B) ore dressers; (C) miners; (D) clerical workers. The symbols ( $\blacktriangle$ ,  $\bullet$ ) denote female and male workers, respectively. \*2.45 and 1.84 ( $\mu\text{g/g}$ ) at 3 months and 6 months, respectively, after the examination.

dence of chronic arsenic poisoning. The symptoms and signs observed in these victims were predominantly arsenodermatitis; hyperkeratosis, warts and arsenomeranosis on the neck, chest, back, abdomen, and the limbs, particularly the legs; and depigmentation, that is leukodermia, on the pigmented areas (known as rain drop pigmentation). Bowen's disease could not be detected. In five of the nine cases, perforation of the nasal septum was observed. The perforation was considered one of the sequelae of inhalation of relatively high concentrations of arsenic trioxide and sulfur dioxide in the arsenic kitchen. The clinical findings observed are shown in Table 4. Other symptoms and signs observed in some of the retired workers who had arsenodermatitis were: hyposmia, anosmia, and peripheral nervous disturbance without central

advised to receive treatment. Typical chronic arsenic poisoning was observed, especially on the skin and mucous membrane, was observed only in the roasters, whereas among miners, ore dressers, and clerical workers, symptoms and signs of chronic arsenic poisoning could not be detected.

Two cases of lung cancer were found in the roasters, but it was difficult to show a higher risk of death by lung cancer in the roasters' group. The incidence of lung cancer in the group seems to be worthy of note, but the population of workers in the mine was too small to analyze the risk of lung cancer mortality statistically.

## Discussion

Arsenic compounds have been widely used for

**Table 4. Major findings in cases diagnosed as chronic arsenic poisoning.**

Case No.	Age	Sex	Type of work	Duration of employment, yr	Time since leaving the mine work, yr	Dermatologic findings	Other findings
10	55	M	Smelter	4	15	Senile leucoderma, leucoderma on the back, hyperkeratosis on the elbow and fingers	Hyposmia
12	55	M	Smelter	14.6	14.5	Alopecia, oligotrichosis of axillary and pubes, pigmentation with leucoderma on the front of left leg, senile leucoderma and verruca	Anosmia, diminishing of sensation
17	60	F	Smelter	5	33	Rain drop leucoderma on the back and frontal chest	Hyposmia
22	55	M	Smelter	10	14	Pigmentation with leucoderma on the neck and frontal chest, senile verruca, oligotrichosis of the eyebrow, pigmentation on dorsal part of fingers and hands, keratosis of the fingers	Perforation of nasal septum
28	53	M	Smelter	4.5	20	Pigmentation and leucoderma on the lower abdomen and extremities	Perforation of nasal septum
42	49	M	Smelter	7	15	Slight pigmentation with leucoderma on the neck, the upper arm and the frontal chest, keratosis, senile pigmentation	Perforation of nasal septum
44	37	M	Smelter	3	14	Scar on the back, tyloma on the palm and fingers	Perforation of nasal septum
57	66	M	Smelter	5	33	Lipoma of the nape (8 cm in diameter), senile pigmentation, pigmentation on the thigh and the elbow	—
59	46	M	Smelter	3.5	15	Senile pigmentation, hyperkeratosis of the palm and fingers.	Perforation of nasal septum

many years as medicine, herbicides, rat-poisons and insecticides. There are many reports of acute and subacute arsenic poisoning by intentional or accidental intake of these compounds (4). In recent years, relatively large-scale arsenic poisoning caused by not only occupational exposure, medication, or foods but also environmental pollution from the refineries has been reported. Birmingham et al. (5) reported an outbreak of contact arsenic skin disease observed on a metal smelter and family members in the adjoining mining community. Perforation of the nasal septum was also observed in roaster operators. Bencko et al. (6) determined arsenic in hair of 10-year-old boys from communities located in the vicinity of a power plant using a local coal of high arsenic content. In the study, they found 3.5 times more arsenic in the hair of these children than in a control group. Similar results in relation to arsenic in hair and urine of children living near a copper smelter were reported by Milham et al. (7). The arsenic levels in hair and urine of the children decreased with distance from the smelter stack, and inhalation was considered the likely exposure route. By a death-record analysis they found an increased incidence of respiratory cancer in workers at the smelter, and they suspected the community surrounding the smelter might be exposed to an increased respiratory cancer risk. Skin cancer and gangrene of the low extremities related to the arsenic in well water were reported by How and Yeh (8). In Japan, Terada et al. (9) found cases

of arsenic poisoning among the population; the subjects were entirely unaware that the well water they used was contaminated with arsenic compounds from the industrial effluent. Major signs observed were arsenic eruption, anemia, leukopenia, and hepatic enlargement. Although there have not been many reports on arsenic poisoning in relation to environmental pollution in the 1970's, an outbreak of chronic arsenic poisoning in the communities adjacent to closed mines was reported by Nakamura et al. (1, 2) and Ishihara et al. (3) in Japan (Table 5).

On the basis of these reports, it was suspected that the workers at the mines were also exposed

**Table 5. Cases of chronic arsenic poisoning in Toroku, Sasagadani, and Matsuo episodes.**

	Toroku (Miyazaki Pref.)	Sasagadani (Shimane Pref.)	Matsuo (Miyazaki Pref.)
Subjects	Inhabitants and workers	Inhabitants and workers	Workers
Source of exposure	Air	Air and water(?)	Air
No. of cases <sup>a</sup>	78 + 1 lung cancer death case	16 + 1 lung cancer death case	11 + 2 lung cancer death cases
Date	Feb. 1, 1973	July 4, 1974	April 1, 1973
Responsible Ministry for Compensation	Environmental Agency and Labor Ministry	Environmental Agency and Labor Ministry	Labor Ministry

<sup>a</sup>As of April 1, 1976.

heavily to arsenic compounds under the uncontrolled working conditions. Follow-up studies of these retired workers are very important for determining late effects of arsenic from the viewpoint of industrial hygiene. The Matsuo mine is one such closed mine located in a mountainous district of Miyazaki Prefecture, Japan. The working environment of the mine was estimated by inspection of the closed mine or smelter, and by asking retired workers about it. According to the roasters, they often worked in the kitchen to collect  $As_2O_3$  without any special protection. They must have been exposed heavily to  $As_2O_3$ .

Many reports on the occupational arsenic poisoning have been published, but there are no reports of late effects or sequelae of arsenic poisoning on the mine workers who left the works more than 10 years ago. In this study, symptoms and signs of the cases diagnosed as chronic arsenic poisoning were quite similar, particularly dermatologically to those reported by Pinto and McGill (10), Birmingham et al. (5), Nakamura et al. (1, 2) and Ishihara et al. (3).

The results of the medical examination on the retired workers of the Matsuo mine indicate that chronic arsenic poisoning was observed only in the roasters or arsenic kitchen workers. No chronic arsenic poisoning was observed in the miners and clerical office workers, even though they might have been exposed to higher levels of arsenic than those in the general residential area. A heavy exposure to arsenic compounds, especially  $As_2O_3$ , and a sufficiently long period of employment at the works in roasting of arsenical ore or arsenic smelting may be responsible for the onset of chronic arsenic poisoning. Moreover, the effects of other pollutants such as sulfur dioxide, lead, selenium, antimony and other heavy metals should also be considered. Unfortunately, there were no available data on the concentration of these substances during the period of the operation of the Matsuo mine.

In conclusion, periodical health examinations for retired or former workers in arsenic mines and refineries are very important for studying the delayed effects of arsenic poisoning. Characteristic symptoms and signs of chronic arsenic poisoning such as arsenodermatitis are more important than the determination of arsenic in urine, blood, and hair.

## Summary

Medical examination of arsenic mine workers who retired or left the works more than 15 years ago

was carried out. Of the 208 workers identified on the basis of employment rosters, 61 received the examination. In the examination 9 out of 21 roasters who often worked in the arsenic kitchen were diagnosed as suffering from chronic arsenic poisoning. The symptoms and signs observed were mainly arsenodermatitis, such as hyperkeratosis, warts, arsenomeranosis, and depigmentation. Perforation of nasal septum was observed in 5 of 9 victims. Other symptoms and signs were hyposmia, peripheral nervous disturbance without central nervous disturbance, and motor paralysis. Evidence of pneumoconiosis, was found in 8 out of 15 miners, but there were no cases diagnosed as arsenic poisoning. Two cases of lung cancer were found in the roasters but because of the small size of the sample it was not possible to show a higher risk of lung cancer in the roasters statistically.

A periodical health examination for retired workers from arsenic mine and refinery is strongly recommended to ascertain the late effects of arsenic poisoning.

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