ENVIRONMENTAL ARSENIC CONTAMINATION AND CONTROL IN SMELTING OPERATIONS

KINGSLEY KAY, M.A., Ph.D., Department of National Health and Welfare, Ottawa, Canada

SUMMARY: Arsenic poisoning has in the past only occurred in areas remote from population centres and has therefore not affected human beings. Human poisoning has recently occurred in a populated area of Canada adjacent to two smelters engaged in the extraction of gold. After poisoning of cattle and humans, a continuous survey was started. A feature of the survey was the urinalysis carried out on local school children. The methods adopted to collect and store the effluent are described. The study shows that even in remote areas population concentrations develop when processes are successful. Operations must be planned with protective measures and uncontrolled stack discharge is not desirable.

As early as 1907, Harkins and Swain reported on assessment of environmental contamination by arsenic from smelting operations. These authors discussed the effect of high stacks and condensing chambers in reducing local contamination. A study of arsenic in vegetation was described by Swain and Harkins in 1908. Concurrently Haywood (1907) and Harkins and Swain (1908) considered injury to vegetation and chronic arsenical poisoning of herbivorous animals. These latter authors reported on the occurrence of fatal arsenic poisoning among cattle grazing in areas close to certain smelters in the Western United States. In these incidents as well as in others which have occurred in the years that followed, poisoning was confined to cattle and wildlife, as the operations concerned were in remote areas not adjacent to centres of population. Recently human poisoning has occurred in a populated area of Canada adjacent to smelting operations where arsenic-bearing roaster fumes were discharged to the atmosphere. Each of these incidents has contributed to knowledge of methods for controlling discharge of such effluents but the Canadian incident has special interest because it involved a populated centre. The changes in environmental levels of arsenic were assessed in relation to changes in roasting process and collection equipment. Furthermore, assessment of urinary levels in children of the area was also carried out, this constituting possibly the first large-scale biological correlation in this field.

In the Canadian situation two roasters, 3 miles apart with a 3,000-person townsite in between, handle locally-mined arsenopyrite ore to drive off arsenic and release the gold content. This process was begun on a production scale several years ago and the arsenic trioxide fume was discharged to the atmosphere. The development of these mines was successful and though the area was remote it did not remain unpopulated for long. Within a few years arsenic pollution had become widespread and occasioned the death of a herd of cattle and some cases of illness to humans. At this stage officers of the Occupational Health Laboratory, Department of National Health were called in to assess the health hazard of the widespread arsenic pollution.

A comprehensive survey was set in motion under which arsenic levels in air, water and vegetation were followed. Assistance from the two mines was obtained in the sampling program. All analyses were by the Gutzeit method.

About a year after production started Mine No. 1 installed an experimental scrubber which collected the fume successfully but produced an arsenic bearing sludge. When the survey began Mine No. 2 was encouraged to install a collection device and Cottrell precipitation was chosen.

The problem of disposing of the collected arsenic was serious. In the mine employing a scrubber, 16 tons of arsenic-bearing sludge were produced per day. This was discharged to a nearby lake and soon raised the level of arsenic in the lake to as high as 40 ppm. Furthermore the contamination began spreading to adjoining lakes used as an occasional source of drinking water. To correct this situation a storage basin was constructed. At Mine No. 2 employing Cottrell collection, chambers were tunnelled out of the permafrost zone between 20 and 100 feet underground. The dry trioxide was pumped into the chambers and sealed off. To date no definite evidence of leakage of arsenic either from the storage basin or the permafrost chambers has been found.

The impinger-scrubber used at Mine No. 1 has continued to collect at efficiencies above 90 per cent. Unfortunately, however, the Cottrell collection efficiency deteriorated in a few years after installation presumably due to increased loading and a change in the composition of the roaster fume as a result of the addition of a vertical type roaster. An additional Cottrell unit was added bringing collection efficiency from 40 to 70 per cent. This was followed by a striking reduction in fall pan collections. Further measures were recommended to raise collection efficiency and a bag collector was chosen. The effect of this measure cannot yet be assessed.

Environmental Sampling Data

Settled Arsenic

At Mine No. 2 collecting by Cottrell, there was a striking reduction in airborne arsenic effluent measured as arsenic settling in fall pans, after the installation of the second Cottrell early in 1955. This is shown in Figure 1. The average figures based on 15 sampling locations within a radius of one mile from the discharge stack have remained low, though further reduction in levels are still sought by the consultants in the interests of reducing environmental contamination to a minimum.

The fall pan data from the smaller mine collecting by impinger-scrubber represent averages of 6 points within a one-mile radius. This is shown in Figure 2. It is evident that levels reflected technical changes related to arsenic discharge, particularly at Mine No. 2 which by virtue of its large tonnage discharge had a substantial effect on settled arsenic in the area of Mine No. 1, a distance of three miles.

Asenic in Water

The levels of arsenic in water are shown in Figures 3 to 8. Tap water was drawn from one large body adjacent to the area. The data show first that spring and early summer water from three tap sources contained arsenic in excess of the safe 8-hour per day continuous intake standard of the United States Public Health Service. This is, of course, due to the

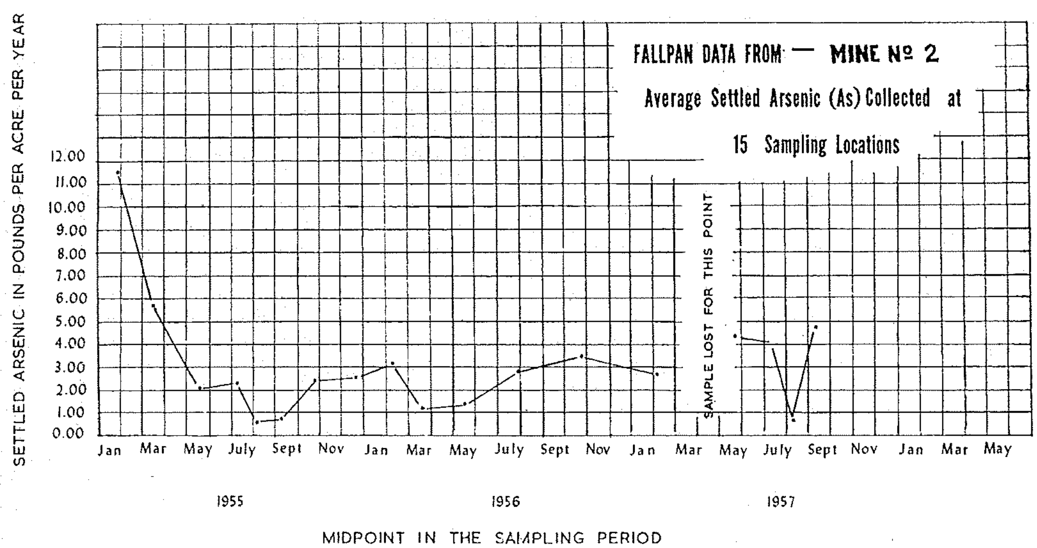


Fig. 1

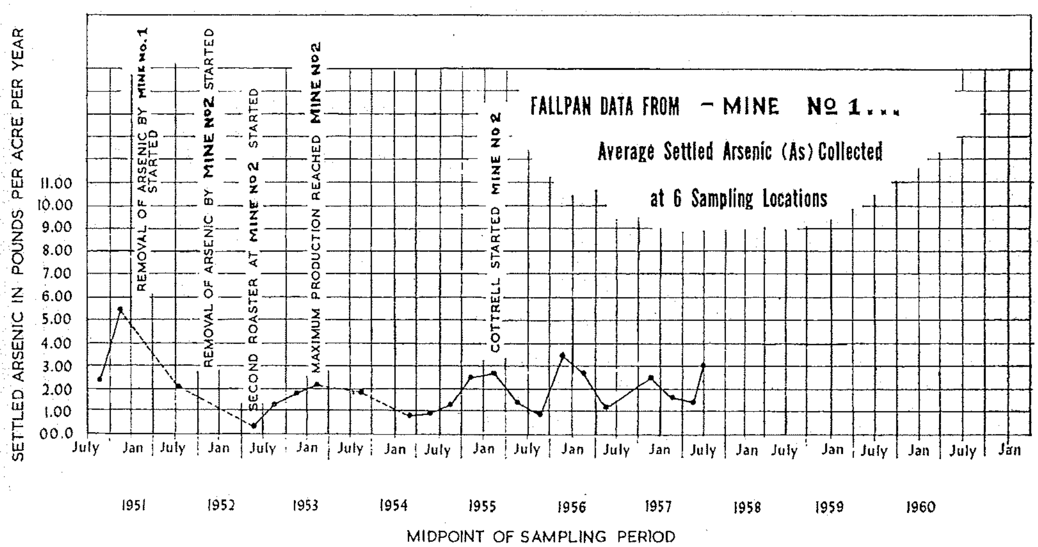


Fig. 2

release of arsenic collected on snow during the winter. Higher levels for the tap water from Mine No. 2 with the Cottrell installation seem to reflect the lower collection efficiency and higher arsenic output. It is to be noted, however, that excessive levels of arsenic were of limited duration.

Figure 8 shows that arsenic in samples from small lakes in each area has been gradually increasing. These were not organized sources of water supply Most of these lakes have no outlet being craters in the rock formation of the area. Presumably they are collectors of arsenic which is being washed into them by rain and at spring melting year by year. The higher values for Mine No. 1 result from the influence of water-discharged arsenic sludge.

Arsenic on Vegetation

The data for arsenic on vegetation has been plotted in Fig. 9. It shows that for either summer or winter samples, arsenic levels in the townsite, between the two mines, were between the levels of mine area samples. There was a reduction in deposited arsenic after the second Cottrell went into use.

Arsenic in Urine of School Children

Groups	Number of Children	Average Arsenic Level	Standard Deviation	Significance of Difference
A. Control[1]	47	0.0058	0.011	A vs. B P <0.01
B. Exposed Group December	40	0.063	0.041	B vs. C P <0.01
C. Same Group April	40	0.027	0.0063	C vs. A P <0.01

[1] Ottawa school children age and sex—matched.

Table 1

Urinary Arsenic

School children were examined and urinalysis done on a statistically valid group around seven years ago and within three years after commencement of discharge of arsenic to the atmosphere. The findings for two sets of tests at six month interval were compared against a group of Ottawa school children. These findings are shown in Table 1. Hospital records showed no effects due to arsenic and the school children were shown to be normal in health. Urines were significantly higher than normal in arsenic but not at toxic levels. Since that time one child has died due to drinking water made from snow. No other effects have been reported and a further clinical appraisal has not been made.

Conclusion

This study of environmental arsenic from discharge of smelter fumes has shown that even in remote areas, population concentrations develop when mining and smelting processes are successful. Thus, public health hazards can develop from discharged effluents. Operations must therefore be planned so as to provide protective measures. Uncontrolled stack discharge or discharge of wastes into nearby water bodies is not desirable. The study has shown the levels of environmental arsenic developing in relation to discharge loads and the urinary excretion of arsenic by exposed children. This review of the available data on the problem of disposal of arsenic wastes from smelters may provide a useful guide for future developments in this field.

Acknowledgment

It is desired to acknowledge the assistance of J. P. Windish in collection of samples and J. L. Monkman in analysis.

BIBLIOGRAPHY

1. Harkins, W. D., Swain, R. D. (1907). The determination of arsenic and other solid constituents of smelter smoke, with a study of the effects of high stacks and large condensing flues. *J. Amer. Chem. Soc.* **29**, 970.
2. Harkins, W. D., Swain, R. E. (1908). The chronic arsenical poisoning of herbivorous animals. *J. Amer. Chem. Soc.* **30**, 928.
3. Haywood, J. K. (1907). Injury to vegetation and animal life by smelter fumes. *J. Amer. Chem. Soc.* **29**, 998.
4. Swain, R. E., Harkins, W. D. (1908). Papers on smelter smoke—arsenic in vegetation exposed to smelter smoke. *J. Amer. Chem. Soc.* **30**, 915.

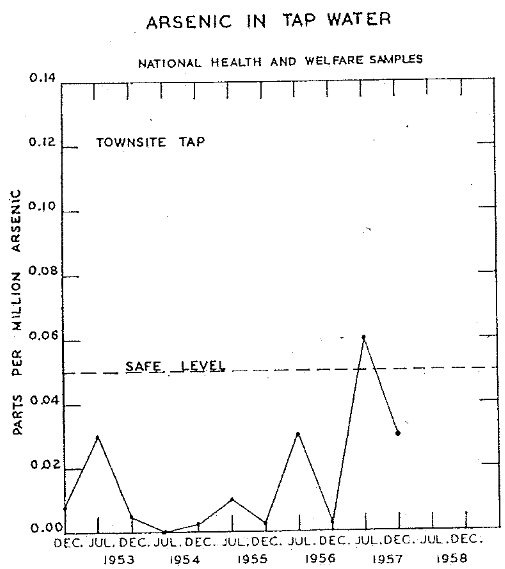
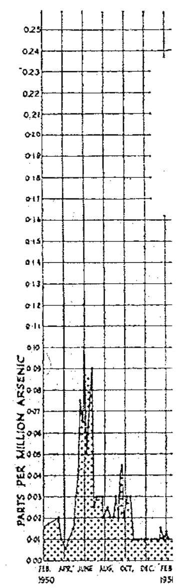
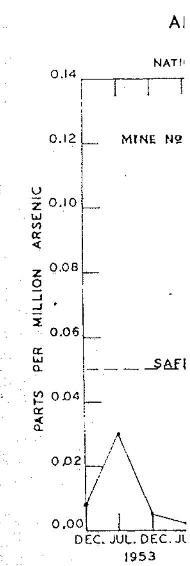


Fig. 3

III. 31





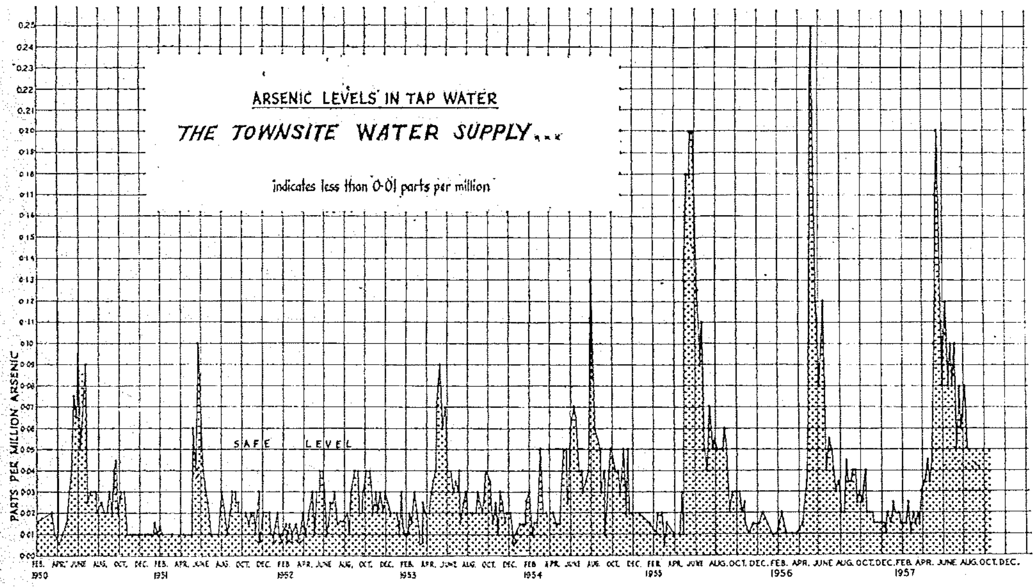


Fig. 4

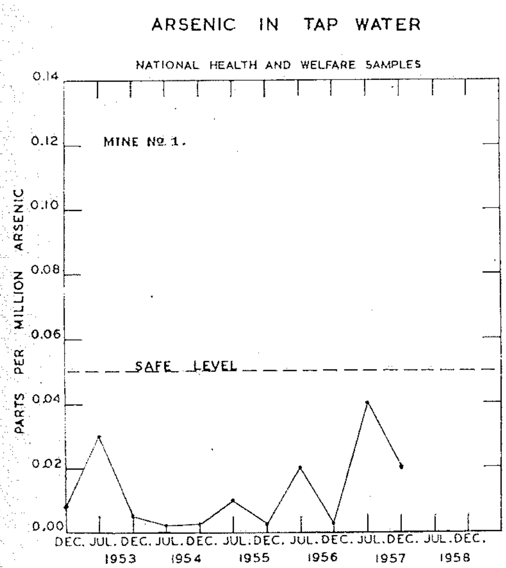


Fig. 5

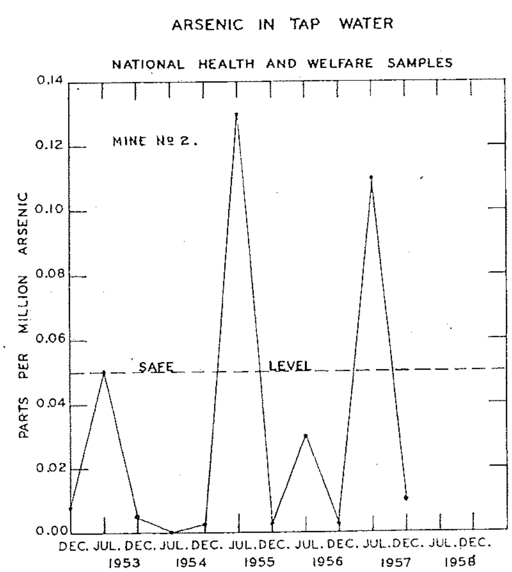


Fig. 6

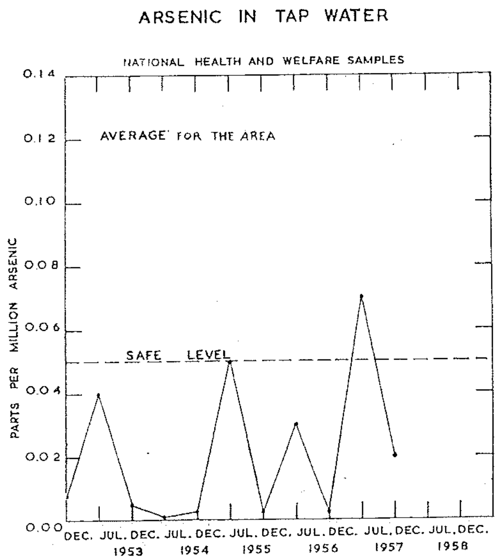


Fig. 7

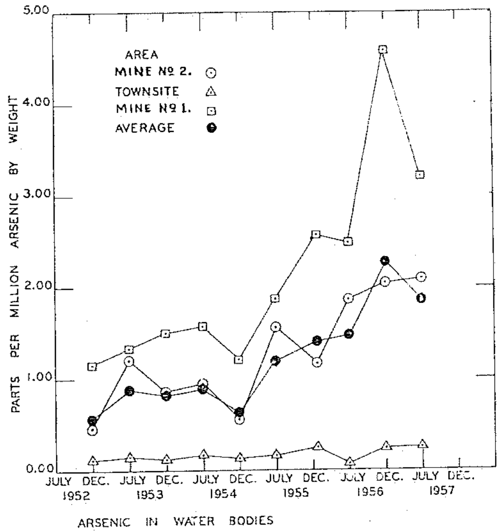


Fig. 8

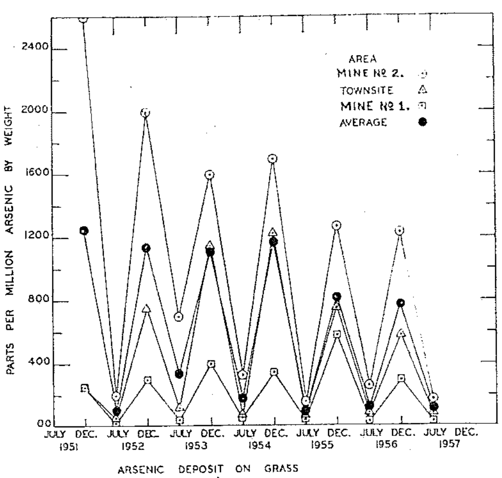


Fig. 9

CHEAPE

Dr. I

SUMMARY
unnecessar
pollution p
An exampl
lene works
by a wet
hibitively
system ha

There is today in
prevention of air
centres for which 3
more of the manu
plant have to be as
as well as of the
economic problem.
prefer a factory wo
ing the neighbou
failure to do this i
However, if the co
high for the facto
to the matter. The
even though the sk
badly smelling air
neighbouring resid
of older plants in p
to impose conditio
answer is " Up to r
few cases is there r
air pollution and o
is no such case.

The answer to
borne depends, hov
factory and whethe
supplementary clea
control, which does
frequently, additio
maintenance. In r
to take the responsi
cleaning equipmen
expenses, particula
process is used only
take into conside
process will soon
processes.

Furthermore, co
the damage has bee
always be carried o
it sometimes happ
make unreasonabl
should be absolved.
that industry today
tion of air pollution
high manufacturing
to put this into act
that means more ec
of emissions.

To develop such
of the noxious sub
pollution, have to b
been the case un
specific processes c
kinds of air polluti
processes. For insta