

Purchased by the Forest Service,
U.S. Department of Agriculture,
for official use.

PLEASE DO NOT REMOVE
FROM FILE

Arsenic Levels in Urine of Forest Workers Applying Silvicides

Robert F. Tarrant, Corvallis, Ore, and Jack Allard, PhD, Wenatchee, Wash

Forest tree thinning workers absorb arsenic from silvicides. Much of the chemical appears to be excreted from the body in a short time. There appears to be no evidence of a continuing increase in arsenic levels over a period of more than two months. Persons using these materials should be trained to observe all necessary precautions to minimize their exposure.

THINNING overdense stands to improve growth rate of trees is one way in which the nation's supply of merchantable timber can be increased significantly.¹ In the Pacific Northwest alone, several million acres of such dense precommercial stands would benefit from thinning.

Two basic methods are used to thin dense forest stands—felling unwanted trees with saws or killing them with chemicals. Economics aside, thinning by felling concentrates slash on the ground and presents a fire hazard, unsightly appearance, and decreased access to forage for livestock and game animals. Chemically killed trees are left standing. The leaves or needles fall first, then the branches, and eventually the stems. Chemical thinning allows better use of for-

age, is esthetically more appealing, and presumably is less of a fire hazard. For these and other reasons, the possibility of using chemicals to kill unwanted trees is of great interest.

Cacodylic acid (dimethylarsinic acid) and monosodium methanearsonate (MSMA) are used by public and private forestry agencies in chemical tree thinning programs throughout the Pacific Northwest and elsewhere in the United States. The chemicals are injected into the tree cambium by a variety of techniques, all of which may expose the worker to the chemicals. Since this forest management technique is used widely, the matter of human safety is of concern.

In 1968, the US Forest Service and the Washington State Department of Health, through its Community Pesticide Study project headquartered at Wenatchee, Wash, obtained preliminary data on the level of arsenic in three thinning crew workers exposed to this element. These observations indicated need for a larger, more sensitive study of the potential for arsenic intake by forest workers using arsenical silvicides. In the study reported here, total arsenic concentration, determined by arsenic levels in the urine, was related to method of application, chemical, and length of time of exposure.

Methods

Three six-man crews from the Wenatchee and Okanogan National Forests in north-

Submitted for publication July 1, 1971; accepted Dec 6.

From Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, Forest Service, US Department of Agriculture, Corvallis, Ore (Mr. Tarrant), and Community Pesticide Study Project, Washington State Department of Health, Wenatchee, Wash (Dr. Allard).

Reprint requests to Pacific Northwest Forest and Range Experiment Station, PO Box 3141, Portland, Ore 97208.

tral Washington were selected for study. Thinning procedures assigned to each of the six men in each crew were recorded in Table 1.

Crewman 1 was a Forest Service employee living and working in the same area as the thinning crew members but not working with chemicals. Crewmen 2 and 3 used the injection hatchet to apply chemical to trees. This tool automatically meters a prescribed amount of chemical into the tree cambium when the blade strikes the tree. Crewmen 4 and 5 used the hack-squirt method of applying the chemical. This involves making a hatchet cut in the tree, into which the chemical is introduced from a plastic squeeze bottle. Crewman 6 used an injector tool which, after impact with the base of the tree, is manipulated to inject chemical from a reservoir in the handle into the cambium layer.

In order to minimize variations in exposure, all study subjects were required to wear similar clothing and use the same safety practices. Every morning each crew member was supplied a set of freshly laundered outer garments consisting of trousers, a shirt, and two pairs of cotton gloves. The gloves, worn at all times while applying the chemicals, were changed at noon or when they became contaminated. Eye protection consisted of goggles or "wrap-around" sunglasses. Adequate cleaning facilities were maintained in the field for each man. The study members were asked to wash their hands before smoking or eating. Crew members filled, cleaned, and generally maintained their own equipment. The chemical dispensing apparatuses were dismantled and thoroughly cleaned at least once a day. Major repairs to equipment were made by the crew foreman. Empty containers and wash water were disposed of by the study members under supervision of the foreman.

The study was carried out during the summer months over a period of nine weeks. Urine samples were collected from each worker in each crew on Monday morning before work was begun and again on the following Friday afternoon at the end of the working day.

Urine was analyzed for total arsenic content by digesting a 100-ml aliquot of sample with a nitric-sulfuric acid mixture to oxidize all organic material. The remaining solution was analyzed for total arsenic by converting any arsenates present to arsine gas, which was trapped in a solution containing silver diethyldithiocarbamate. Arsine in the presence of this carbamate forms a colored complex. The color intensity was measured, and the amount of arsenic present in the original urine sample was calculated. In lieu of 24-hour collections, urine con-

Table 1.—Thinning Procedures Assigned to Men in Each Crew

Crewman	Chemical Used	Application Method
1	None	None
2	Cacodylic acid	Injection hatchet
3	MSMA	Injection hatchet
4	Cacodylic acid	Hack-squirt
5	MSMA	Hack-squirt
6	MSMA	Injector tool

centration differences were corrected by use of osmolality values. The analytical method² proved sensitive to 0.01 ppm. Arsenic recovery ranged between 85% and 100%.

Results and Comment

Absence of workers for a variety of reasons made it difficult to obtain urine samples from every study participant at every sampling time. Data are missing in at least one instance for every week except the fourth (Table 2). However, complete data are available for weeks 2, 3, 4, 7, and 8, except for the treatment by the injection hatchet with cacodylic acid. Results of an analysis of variance performed on these complete data indicate that the arsenic content of urine of workers exposed to chemicals was significantly higher than that of workers in the control group (Table 3). There were no significant differences among the noncontrol treatments.

Concentration levels of total arsenic in urine were elevated after a week of exposure to the chemicals regardless of the method of application or chemical used. The high values observed on Friday were, in most instances, near normal again on Monday. In individual cases where a very high value (over 1 ppm) was measured on Friday, the weekend absence from contact with the chemicals did not allow sufficient time for arsenic levels to return to normal. Therefore, Monday values were relatively high in these instances.

Greatly elevated arsenic values could generally be explained as the result of unusual exposure, eg, the men may have accidentally cut themselves with hatchets, spilled chemicals on their clothing and skin, had to make frequent equipment repairs, or may have become lax in their safety habits. Statistical analysis shows that arsenic concentrations in urine on Fridays were significantly great-

er than those measured in samples taken on Mondays (Table 3). Thus, we conclude that the generally higher values found on Friday were real and that arsenic concentration in urine will increase during any work week. However, there was no indication of a continuing increase over the nine-week study period.

Complete data were available for all treatments, including that with the injection hatchet with cacodylic acid only, on the basis of Friday observations for weeks 2, 3, 4, and 6. These data were analyzed to compare arsenic levels in urine on the basis of chemical used and on the two methods of application, hack-squirt and injection hatchet. The difference between chemicals was not statistically significant (Table 4). Neither was the difference between application methods, although with both MSMA and cacodylic acid arsenic concentration of urine of workers using the injection hatchet was substantially greater than that of those employing the hack-squirt method.

The arsenic level of urine at which concern for matters of health should begin is not well known. A manufacturer of arsenical silvicides states: Because some individuals are more sensitive than others, it is advisable to always be on the lookout for signs of skin sensitivity among persons handling arsenicals. When a person shows sensitivity, he should be removed from exposure. When an individual is exposed daily for extended periods, the inspection for skin sensitivity should be supplemented by monthly urine analysis for arsenic. . . . When a sample shows above about 0.3 mg of arsenic per liter, another sample should be taken and if again above this figure, the donor should be removed

Table 2.—Total Arsenic Concentration in Urine of Forest Workers Variously Exposed to Arsenical Silvicides: Means of Three Observations

Treatment	Week								
	1	2	3	4	5	6	7	8	9
	Total Arsenic (ppm)								
Monday									
Control, no exposure	...	* 0.03	0.05	0.01	0.02	0.03	0.07	0.02	0.07
Injector, MSMA	...	0.08	0.07	0.09	0.05	...	0.10	0.13	0.05
Hack-squirt, MSMA	0.02	0.06	0.04	0.07	0.07	0.10	0.12	0.07	...
Hack-squirt, cacodylic acid	0.02	0.09	0.06	0.06	...	0.15	0.12	0.09	0.09
Injection hatchet, MSMA	...	0.09	0.08	0.04	0.05	0.12	0.13	0.17	...
Injection hatchet, cacodylic acid	...	...	...	0.20	0.21	...	0.37	...	...
Friday									
Control, no exposure	...	0.06	0.04	0.05	...	0.03	0.04	0.14	...
Injector, MSMA	0.18	0.35	0.24	0.58	0.25	0.34	0.56	0.07	...
Hack-squirt, MSMA	0.27	0.26	0.30	0.19	0.23	0.42	0.36	0.20	0.22
Hack-squirt, cacodylic acid	0.22	0.40	0.28	0.51	0.31	0.50	0.51	0.32	0.29
Injection hatchet, MSMA	0.35	0.93	0.26	0.49	0.24	0.54	0.28	0.53	...
Injection hatchet, cacodylic acid	...	0.64	0.76	0.50	0.75	0.88	...	...	...

* Data missing for at least one of three replications (workers).

Table 3.—Means of Three Observations of Arsenic Levels in Exposed Workers for Weeks 2, 3, 4, 7, and 8

Treatment*	Total Arsenic (ppm)	
	Monday	Friday
Control, no exposure	0.04 ± 0.01	0.07 ± 0.03
Injector, MSMA	0.10 ± 0.01	0.36 ± 0.07
Hack-squirt, cacodylic acid	0.03 ± 0.01	0.41 ± 0.08
Hack-squirt, MSMA	0.07 ± 0.01	0.26 ± 0.05
Injection hatchet, MSMA†	0.10 ± 0.01	0.50 ± 0.12
Av of all treatments	0.08 ± 0.01	0.32 ± 0.03

* Control is significantly lower (5% level of probability) than all chemical treatments. No chemical treatment is significantly different from any other. Monday concentrations are significantly lower than those of Friday.

† Injection hatchet-cacodylic acid treatment not included in analysis because of missing data. Means (in ppm) for weeks 4 and 5 are: Monday, 0.21; Friday, 0.63.

Table 4.—Mean Total Arsenic Concentration in Exposed Workers by Chemical and Method of Application

Treatment	Mean* ± SE (ppm)
Chemicals	
MSMA	0.42 ± 0.08
Cacodylic acid	0.56 ± 0.09
Application methods	
Hack-squirt	0.36 ± 0.05
Injection hatchet	0.62 ± 0.10

* Differences between the two chemical means and between the two method means were not significant when tested at the 5% probability level.

Table 5.—Comparison of Friday and Following Monday Levels of Arsenic and Observations in Which Total Arsenic Exceeded 0.3 ppm

Treatment	Total Observations	Observations in Which Total Arsenic Exceeded 0.3 ppm	
		Friday	Following Monday
Control, no exposure	23	1	0
Hack-squirt, MSMA	25	8	0
Injector, MSMA	24	10	0
Hack-squirt, cacodylic acid	24	11	0
Injection hatchet, cacodylic acid	18	12	5
Injection hatchet, MSMA	24	13	0

from exposure. Actual experience with . . . (persons involved in the manufacturing operation of arsenical materials) . . . shows that removal from exposure quickly reduces the urine arsenic level to normal and eliminates the signs of skin sensitivity.³

All but one of the 15 men applying the chemicals in this study had urine arsenic levels in excess of 0.3 ppm at least once during their period of exposure. The highest level recorded was 2.5 ppm. However, except for those workers using the injection hatchet with cacodylic acid, in all subjects in whom the Friday arsenic level exceeded 0.3 ppm, the level on the following Monday was always less than 0.3 ppm (Table 5).

No health problems were encountered in the study group that could be classified as arsenic poisoning. There were 136 man-weeks of exposure to arsenical silvicides recorded for study members. During that exposure period, 14 men complained of headaches, six of abdominal cramps, five of weakness, four of nausea, and one of skin rash. The controls, observed for 27 man-weeks, had one episode of nausea and one of weakness. The number of persons, especially controls, under observation was small; and no firm conclusions can be drawn, although the large number of reports of headache may have some significance. The crew members were aware that they were part of a health study of an arsenic compound and, as a result, may have overreported symptoms. They did not, however, have an increased rate of sick leave over other Forest Service employees.

Conclusions

Forest tree thinning workers absorb arsenic from silvicides, much of which appears to be excreted from the body in a short time. Measurements over a period of more than two months indicated there was no increase in levels of arsenic in urine after the first week. However, excretion was always greater at the end of each work week than after weekend absence from contact with the chemicals.

Most workers in this study exceeded a total arsenic concentration of 0.3 ppm in urine on one or more occasions during the study. No evaluation of the health effects of this exposure can be made from this study.

The amount of arsenic absorbed by workers could not be related to kinds of arsenical chemicals used or to methods of application.

This study indicates the possibility that tree thinning workers are exposed to excessive quantities of arsenic. Thinning crews using these materials must be trained to avoid skin contact with the chemicals. Protective clothing, including gloves of material impervious to the chemical solution, is most necessary. Water-repellent cream should be used on the face and any other skin areas that cannot otherwise be protected. Extreme care must always be used in handling chemicals, especially when filling application tools where the danger of spillage is great. Furthermore, facilities must be provided for thorough hand and face washing after periods of chemical use.

References

1. *Douglas-Fir Supply Study*. Portland, Ore, US Dept of Agriculture Forest Service, 1969.
2. Steckel LM, Hall JR: *Spectro-Photometric Determination of Trace Arsenic in Aluminum Alloys, Aluminum, Uranium, and Lead*, AEC Research and Development report Y-1406 (chemistry). Atomic Energy Commission, 1962.
3. *Safety and Handling of Ansul Herbicides*, bulletin. Ansul Co Chemical Products Division.