

Arsenic Levels in Oregon Waters

by P. D. Whanger,* P. H. Weswig, and
J. C. Stoner†

The arsenic content of well water in certain areas of Oregon can range up to 30 to 40 times the U.S.P.H.S. Drinking Water Standard of 1962, where concentrations in excess of 50 ppb are grounds for rejection. The elevated arsenic levels in water are postulated to be due to volcanic deposits. Wells in central Lane County, Oregon, that are known to contain arsenic rich water are in an area underlain by a particular group of sedimentary and volcanic rocks, which geologists have named the Fischer formation. The arsenic levels in water from wells ranged from no detectable amounts to 2,000 ppb. In general the deeper wells contained higher arsenic water. The high arsenic waters are characterized by the small amounts of calcium and magnesium in relation to that of sodium, a high content of boron, and a high pH. Water from some hot springs in other areas of Oregon was found to range as high as 900 ppb arsenic. Arsenic blood levels ranged from 32 ppb for people living in areas where water is low in arsenic to 250 ppb for those living in areas where water is known to contain high levels of arsenic. Some health problems associated with consumption of arsenic-rich water are discussed.

Although high arsenic levels are found in several water sources in Oregon, that found in ground water in Lane County has received the most attention. This is because several cities or towns are located in the high arsenic water areas of this county, whereas other areas of the state where high arsenic water is found are not densely populated. Lane County is located in Western Oregon midway between the Columbia River and the northern boundary of California (Fig. 1). It extends from the Pacific Ocean on the west to the crest of the beautiful, snowcapped Cascade Mountains on the east. The natural occurrence of arsenic in ground water of Lane County is the only one in a well populated area of the North American continent (1).

In 1962 the Lane County Health Department became involved in the arsenic water problem (1). Some residents near a cherry processing plant adjacent to the city of Eugene stated that their water which came from shallow irrigation wells tasted and smelled like fermented cherry juice. This was most pronounced during the cherry canning season. The water was found to contain significant levels of ar-

senic. During this time, a physician reported a case of arsenic toxicity to the Health Department. Analysis of water from the patient's well indicated an elevated arsenic content. This news alarmed the local citizens and a widespread investigation of the arsenic content in ground water in Lane County was undertaken.

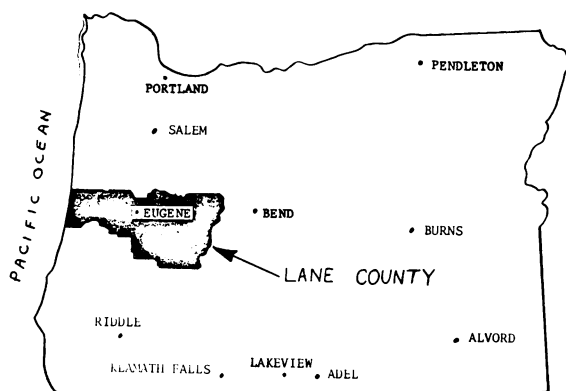


FIGURE 1. Map of Oregon showing location of Lane County, location of principal cities, and areas where hot springs are present.

*Department of Agricultural Chemistry, Oregon State University, Corvallis, Oregon 97331.

†Environmental Health Division, Department of Community Health and Social Services, Lane County, Eugene, Oregon 97473.

According to the geologists, this arsenic-rich ground water problem is due to the volcanic events leading to the formation of the Cascade and Pacific

Coast Mountain ranges. Wells in central Lane County which are known to yield arsenic-rich ground water are in an area underlain by a particular group of sedimentary and volcanic rocks, which geologists have named the Fischer formation (2-4). Since the high arsenic ground water is apparently associated with the Fischer formation, the extent of this formation can be used to mark the possible occurrence of arsenic-rich water. The Fischer formation extends north and south from the town of Cottage Grove, and surrounds the city of Eugene (Fig. 2). A finger projection extends towards Junction City. Several deposits of this formation are also found northeast of the city of Eugene.

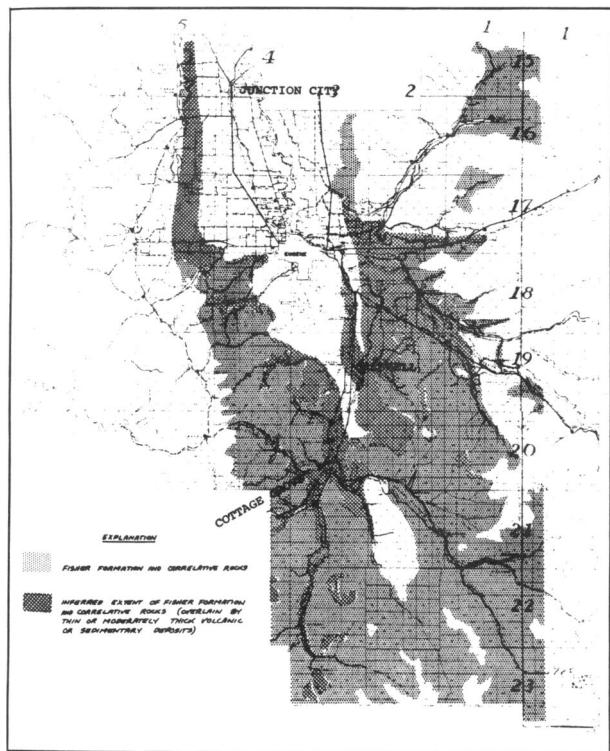


FIGURE 2. Map of central Lane County showing the Fischer formation and location of towns in this area.

About 45 million years ago, according to the geologists, during the last part of the Eocene Epoch of geologic time, much of Lane County was above sea level. This was underlain by older marine sedimentary deposits. Vigorous volcanic eruptions where the Central Cascades are now located scattered large amounts of airborne volcanic (pyroclastic) debris over the surrounding areas. The volcanic activity and deposition of this pyroclastic debris continued for 10 to 15 million years. The resulting accumulation of volcanic deposits was called the Fischer formation (2). The largest concentrations of

arsenic occur in the central and eastern parts of this formation, which are also the younger parts.

The common characteristics of the arsenic-rich ground waters are the small amounts of calcium and magnesium in relation to that of sodium, a high content of boron, and high pH value. A high concentration of orthophosphate is common, but the total dissolved solids, concentrations of sulfate and chloride are variable. There are several theories concerning the accumulation of arsenic in the ground water. The most accepted theory is the one indicating an igneous source (1). This source is suspect for both arsenic and boron since these elements are often associated with igneous and related activity. Mineralogical and chemical changes within rocks of the Fischer formation subsequent to their deposition are most likely the sequence of events resulting in soft, arsenic- and boron-rich, high pH ground water. The arsenic as well as the boron was probably a part of the airborne pyroclastic debris that formed the Fischer rocks. After deposition, certain minerals within the rock undoubtedly were altered chemically by percolating subsurface water. The minerals were largely converted to clays, and simultaneously the water was naturally softened when calcium and magnesium in the water were replaced by sodium from the rocks. A gradual increase in pH and arsenic content probably accompanied the natural water softening which was associated with chemical and mineralogical rock alteration. Presumably, the arsenic was released from the rocks along with sodium.

An intensive well-water sampling program in central Lane County covering 100 square miles was conducted in 1962 and 1963. A total of 174 wells were chosen, ranging in depth from 20 to more than 300 ft. The well and casing depths of the wells, and a detailed description of geological materials penetrating the wells were known for the chosen wells. The results of this study are presented in Table 1. Many samples contained more than 10 ppb arsenic, and concentrations greater than 50 ppb were not uncommon. The highest concentration of arsenic in well water was found to be 1700 ppb. In general, the water from deeper wells contained more arsenic than from shallow ones. The greatest concentrations of arsenic were found in samples from the Creswell area (see Fig. 2 for location of town). Among 30 well water samples from that district, 12 contained more than 100 ppb of arsenic and of those, five contained more than 500 ppb.

A more extensive study was conducted from 1968 to 1974 on the arsenic content of well water (5). The areas were divided as indicated in Figure 3. The water from the rural area of south Lane County had the highest arsenic concentrations (Table 2). Only

Table 1. Lane County water arsenic levels, 1962-1963.^a

Range in arsenic concentrations, ppb	Number of wells with water having arsenic concentration within range
0-10	121
20-50	26
60-100	8
110-500	14
<500	5

^aData of Goldblatt et al. (1).

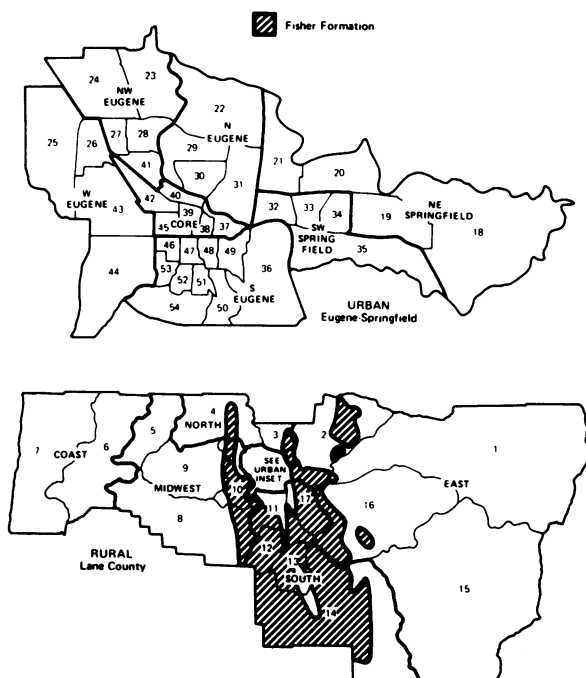


FIGURE 3. Map showing census tracts and regions in urban and rural Lane County, Oregon.

Table 2. Lane County water arsenic levels, 1968-1974.

Geographic region	Arsenic, ppb		
	Mean	Range	Number of samples
Rural	16.5	0-2150	491
North	7.6	0-24	29
East	11.8	0-70	80
South	33.0	0-2150	186
Midwest	9.7	0-107	159
Coast	4.7	0-13	37
Urban	4.8	0-860	67
NE Springfield	3.9	0-8	14
SE Springfield	6.0	0-30	4
S Eugene	5.3	0-750	10
W Eugene	6.5	0-860	20
NW Eugene	3.8	0-8	6
N Eugene	3.8	0-8	8
Core Eugene	4.0	0-8	5
Lane County	8.6	0-2150	558

^aData of Morton et al. (5).

45 of the arsenic values were 50 ppb or higher. Probably one of the reasons for this is that the small towns and water districts in these areas, known to overlie the Fischer formation, often had chosen surface water source rather than a deep well because of the known arsenic hazards. Within the urban area the ground water south and west of Eugene had the highest arsenic content. Since these areas are closest to the Fischer formation, the high arsenic levels are presumably a reflection of this formation. Recent analysis has indicated that the majority (about 95%) of the arsenic in these waters is in the form of arsenate (6).

A study was made on the arsenic content in various municipal water supplies for several cities in Oregon. The level of this element was very low in the water supplies; all samples were 6 ppb or less. This is consistent with the general observations indicating the ground waters to be the contributors of arsenic. Municipal water supplies are obtained from lakes, rivers or reservoirs.

Another study indicated that some hot springs of Oregon contain high arsenic levels (Table 3). The water supply for the town of Lakeview (see Fig. 1 for location in state) contained very low levels of

Table 3. Arsenic levels in water from different sources in Oregon.

Water source	Arsenic content, ppb
Lakeview (town water supply)	7
Hot Springs, south of Lakeview	133
Hot Springs, north of Lakeview	200
Mann Lake (Alvord)	<1
Tudor Creek (Alvord)	<1
Willow Creek (Alvord)	6
Juniper Lake (Alvord)	9
Alvord Well (No. 1)	19
Mickey Hot Springs (Alvord)	900
Alvord Lake	7
Hot Springs (South of Alvord Lake)	645
Cold Springs near Hot Springs (south of Alvord Lake)	330
Crump Lake (Adel)	9
Crump Geyser (Adel)	690

this element, but the hot springs near this town contained up to 200 ppb. Likewise, the lakes and creeks at Alvord contain low levels of this element, but the hot springs contain high levels of this element. This is similar to the pattern for Crump Lake and Crump Geyser near Adel, Oregon. The cold springs near the hot springs at Alvord containing elevated arsenic levels suggest that the water from the latter springs may be contributing to the former ones. Thus, the hot springs of this area of Oregon can contain significant levels of this element.

A limited study was conducted on the arsenic content of blood from residents of various cities in Oregon. The levels of this element were signifi-

cantly higher in blood of residents from Riddle or Cottage Grove than in blood from those in other cities (Table 4). This limited information indicates that the blood arsenic levels of people probably reflects their arsenic intake, since the highest levels were in blood from residents living in areas where arsenic-rich water is known to be present. The blood from the Eugene residents were taken from those supplied with municipal water. This probably accounts for the low values. This data indicate that further studies on the relationship of blood arsenic levels to the amount present in drinking water for man would provide useful information.

Table 4. Blood arsenic levels of some Oregon residents.

City	Blood arsenic, ppb		
	Mean	Range	Number of samples
Pendleton	32 ^a	10-90	11
Klamath Falls	49 ^a	10-100	12
Portland	60 ^a	10-100	6
Eugene	65 ^a	10-110	6
Riddle	122 ^b	110-140	9
Cottage Grove	251 ^a	90-360	9

^aa and b are significantly different at 1% level ($p < 0.01$).

Exposure of man to arsenicals has been shown to elevate the urinary output of arsenic (7). Urine levels, however, appeared to be a better indication of arsenic exposure than blood levels. Arsenic is excreted in the urine of man in several different chemical forms (8), even though one primary form was ingested. This indicated that changes in chemical forms of this element can occur within the body. Since species differences of blood levels with relation to intake have been noted (9), blood levels may not be a good indication of exposure in some animals.

Very little evidence is available to indicate that the arsenic levels in the waters of Lane County cause acute toxicity, but sufficient evidence is available to indicate some chronic problems. Before arsenic was known to be present in this water, there may have been some serious health problems due to the consumption of the arsenic-rich water. Now that the problem areas have been identified, the water is analyzed for this element when a patient exhibits symptoms resembling in any way an excessive level of arsenic. If the element is present in water above accepted levels, a new water source is found.

No relationship between the arsenic levels in water to incidence of skin cancer was found in a study conducted between 1968 and 1974 (5). A positive association between the arsenic levels of drinking water and prevalence of skin cancer in endemic areas of chronic arsenicism was reported from

Germany and Argentina (10), from Taiwan (11), and from Chile (12). Probably the reason for a lack of correlation in the Lane County study was because the arsenic levels were not high enough in the water to cause or promote this disorder. The levels of arsenic in water from these other countries are higher than that in Lane County water. As an example, only 5% of the water samples during the 1968-1974 study in Lane County (5) was found to contain 100 ppb or more whereas 48% of samples in the Taiwan study contained 100 ppb or more (11).

A few examples of possible arsenic toxicity are given to indicate the symptoms associated with this problem. A family, composed of father and mother, two children and the wife's mother, consumed well water containing 420 ppb arsenic for 5 yr. Except for the grandmother having tingling sensations of the fingers, no physical complaints were made by the family members. Urinary arsenic tests showed a range of 90 ppb for the boy to 400 ppb for the mother (normal levels are usually less than 100 ppb). The arsenic in hair ranged from 6000 ppb for the girl to a high of 28,000 ppb for the boy. Arsenic analysis of the nail samples indicated a low of 8000 ppb for the father to a high of 16,000 ppb for the girl. Thus, no correlation existed between the levels of this element in the three samples from these family members, suggesting other factors may need to be considered.

A girl about 3 years old in another family had a skin problem. About 6 months after she was taken off their well water, this skin condition improved markedly. The father had gastrointestinal problems which cleared up when the water supply was changed. The mother and two sons, however, had no problems, indicating possible differences in individual susceptibility to this element in water. This family's water analyzed 320 ppb arsenic.

Another suspected arsenic toxicity was with a group of nuns engaged in making pottery. The symptoms noted by the nuns in the cloister included lassitude, headaches, tinglings of fingers and toes, slight tension, and mild to moderate anemia. The hair samples analyzed an average of 165 ppm arsenic. The source of this element was never identified (their water was about 10 ppb), but their conditions improved when several changes were made in their operations for making pottery.

A final example concerned a lady who was admitted to a local hospital with the preliminary diagnosis of bone-marrow depression. Her complaints began about 4 months prior to admission but had accelerated the last month. These included nausea, vomiting, loss of weight (40 lb before hospitalization), and tingling and burning paresthesias of hands and feet. Smoking was distinctly unpleasant for her. Hyper-

keratosis and desquamation were noted on the palms of her hands and soles of her feet. The urinary arsenic was 530 ppb when admitted but had decreased to 40 ppb when released from the hospital. The patient recovered rapidly but the paresthesias persisted for some time. Since her well water analyzed 1700 ppb arsenic, this arsenic-rich water was assumed to have caused or contributed to the symptoms and the well was abandoned as a source of drinking water.

These examples indicate that it is not easy to diagnose arsenic toxicity solely on the basis of symptoms. The tingling of hands and feet appear to be a common symptom, but many other problems will also cause this sensation. Arsenic levels of hair, nails and urine appear to be the most reliable indication of excessive intakes of this element. Of course, this is not usually measured unless there is suspected arsenic toxicity. At present, no clear-cut symptoms unique to arsenic toxicity are available to lead to such tests.

REFERENCES

1. Goldblatt, E. L., Van Denburgh, A. S., and Marsland, R. A. The unusual and widespread occurrence of arsenic in well waters of Lane County, Oregon. Lane County Health Department Monograph, Eugene, Oregon, 1963.
2. Hoover, L. Geology of the Anlauf and Drain Quadrangles, Douglas and Lane Counties. Oregon U. S. Geology Survey Bull. 1122-D (1963).
3. Peck, D. L. Geologic Map of Oregon West of the 121st Meridian. U. S. Geol. Survey Misc. Inv. Map I—325 (1961).
4. Vokes, H. E., Snavely, P. D., and Myers, D. A. Geology of the Southern and Southwestern Border Areas of the Willamette Valley, Oregon. U. S. Geol. Surv. Oil and Gas Inv. Map OM-110 (1951).
5. Morton, W. et al. Skin cancer and water arsenic in Lane County, Oregon. *Cancer* 37: 2523 (1976).
6. Crecelius, E. A. Unpublished observation. Battelle Pacific-Northwest Laboratories, Marine Research Laboratory, Sequim, Wash.
7. Wagner, S. L., and Weswig, P. H. Arsenic in blood and urine of forest workers. *Arch. Environ. Health* 28: 77 (1974).
8. Crecelius, E. A. Chemical changes in arsenic following ingestion by man. Paper presented at 15th Annual Hanford Life Sciences Symposium, Richland, Wash., 1975.
9. Whanger, P. D., et al. Effects of selenium, cadmium, mercury, tellurium, arsenic, silver and cobalt on white muscle disease in lambs and effect of dietary forms of arsenic on its accumulation in tissues. *Nutr. Rep. Intern.* 14: 63 (1976).
10. Buchman, W. E. *Toxicity of Arsenic Compounds*. Elsevier, New York, 1962.
11. Tseng, W. P. et al. Prevalence of skin cancer in an endemic area of chronic arsenicism. *J. Nutr. Cancer Inst.* 40: 453 (1968).
12. Zaldivar, R. Arsenic contamination of drinking water and foodstuffs causing endemic chronic poisoning. *Beitr. Pathol.* 151: 384 (1974).