Advances in
ENVIRONMENTAL SCIENCE AND TECHNOLOGY

Volume 3

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ENVIRONMENTAL SCIENCE AND TECHNOLOGY

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INTRODUCTION TO THE SERIES

Advances in Environmental Science and Technology is a series of multiauthored books devoted to the study of the quality of the environment and to the technology of its conservation. Environmental sciences relate, therefore, to the chemical, physical, and biological changes in the environment through contamination or modification; to the physical nature and biological behavior of air, water, soil, food, and waste as they are affected by man's agricultural, industrial, and social activities; and to the application of science and technology to the control and improvement of environmental quality.

The deterioration of environmental quality, which began when man first assembled into villages and utilized fire, has existed as a serious problem since the industrial revolution. In the second half of the twentieth century, under the ever-increasing impacts of exponentially growing population and of industrializing society, environmental contamination of air, water, soil, and food has become a threat to the continued existence of many plant and animal communities of the ecosystem and may ultimately threaten the very survival of the human race.

It seems clear that if we are to preserve for future generations some semblance of the existing biological order and if we hope to improve on the deteriorating standards of urban public health, environmental sciences and technology must quickly come to play a dominant role in designing our social and industrial structure for tomorrow. Scientifically rigorous criteria of environmental quality must be developed and, based in part on these, realistic standards must be established, so that our technological progress can be tailored to meet such standards. Civilization will continue to require increasing amounts of fuels, transportation, industrial chemicals, fertilizers, pesticides, and countless other products, as well as to produce waste products of all descriptions. What is urgently needed is a total systems approach to modern civilization through which the pooled talents of scientists and engineers, in cooperation with social scientists and the medical profession, can be focused on the development of order and equilibrium among the presently disparate segments of the human environment. Most of the skills and tools that are needed already exist. Surely a technology that has created manifold environmental problems is also capable of solving them. It is our hope that the series in Environmental Science and Technology will not only serve to make this challenge more explicit to the established professional but will also help to stimulate the student toward the career opportunities in this vital area.

Finally, the chapters in this series of Advances are written by experts in their respective disciplines, who also are involved with the broad scope of environmental science. As editors, we asked the authors to give their "points of view" on key questions; we were not concerned simply with literature surveys. They have responded in a gratifying manner with thoughtful and challenging statements on critical environmental problems.

We are pleased that Dr. Alan C. Lloyd, Assistant Director of the University of California Statewide Air Pollution Research Center, will act as Associate Editor to the Series.

To facilitate communications with our contributors and readers, we are including below our addresses and telephone numbers.

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Contents

Lead in the Environment

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I. INTRODUCTION

Lead is a useful, easily formed, and durable metal which mankind has utilized since pre-Christian times. While it has many uses and will combine with other chemicals to give new compounds with unique properties, it also has been shown to have definite deleterious human health effects in small quantities in the body.

While many elements are required by the human body in small or trace amounts, lead has no known beneficial effect upon human health upon ingestion. Acute toxicity effects have been observed upon the introduction of excessive quantities.

Lead has many beneficial uses. No other materials are as suitable for some of these purposes. Examples include shielding against electromagnetic radiation, lining of tanks or drain pipes where very corrosive chemicals are being processed, and storage batteries. Because of its usefulness, production and utilization of lead may be expected to continue. At the same time, its potential for hazard should be understood so that the hazard may be controlled.

An excellent, recent, short (34 pages) report on the source, dosage, and toxicity of lead in man has been prepared by Engel et al. (1) as one of the Environmental Health Series publications. A longer and very important report, also recent, is that prepared by the National Academy of Sciences-National Research Council (2).

II. PRODUCTION AND UTILIZATION OF LEAD

A. Naturally Occurring Lead

The average magnitude of the lead content of the earth's crust is approximately 16 micrograms per gram (μg/g) of soil (3). Basic rocks have a concentration of lead up to 8 μg/g and acidic rocks have concentrations up to 20 μg/g. The majority of naturally occurring lead is in the form of minerals: Galena (lead sulfide), Cerussite (lead carbonate), and Anglesite (lead sulfate). Galena is the most common form.

Other naturally occurring lead is the result of the decay of Uranium-238, which occurs in trace amounts in the soil. Uranium-238 decays through a series of radioactive elements until the stable nuclide lead ends the chain. While most of the elements in the chain and the end product, lead, remain in the soil, one of the radioactive elements is a gas, Radon-222. A small portion of the gas diffuses from the earth into the atmosphere. There, stable lead eventually is produced. As the escape from the earth is very small, 1 to 1.5 x 10^{-16} curies per square centimeter per second (4), the contribution to atmospheric lead also is very small.

B. Mining, Smelting, and Refining

The lead content of ore mined in the United States is generally low, ranging from 2 to 8% (5). Lead content frequently is higher abroad. The main sources of lead in this country are primary mining, smelting, and refining; secondary recovery; and imports.

Tables I and II and Figure 1 illustrate the locations of U. S. lead production mines, smelters, and refineries with the production for 1968 and 1970 shown in Table I. During 1970, these mines produced approximately 579,000 short tons (1 short ton = 2000 pounds) of lead with Missouri, Idaho, and Utah accounting for 91% of the domestic output.

Six companies (Table III) produced approximately 1,100,000 tons of lead in 1969 and 1970 by refining and primary smelting. Imported lead decreased from 500,000 short tons in 1967 to 245,000 tons in 1970. This, added to the lead produced at primary refineries and secondary smelters in the U.S., gave a total new supply of approximately 1.54 million short tons in 1970.

Once ore is mined, it is concentrated to a content of 60 to 80% lead by a process called flotation before being sent to smelters. During flotation, finely ground ore is mixed with water and chemicals selected to cause the heavy lead particles to rise to the surface in a froth and overflow. Primary lead smelters and refineries then convert the concentrated lead ore to pig lead after removal of varying percentages of zinc, silver, copper, arsenic, and other minerals originally in the mined ore.

Secondary smelting also is an important source of lead. In 1970, approximately 590,000 short tons of lead were recovered by secondary smelting. Secondary smelting is the recovery of lead from scrap, primarily from old storage batteries. Approximately 55% of all lead used is recovered. While primary smelters are relatively few and generally large, secondary smelters tend to be numerous with a wide distribution of sizes.

TABLE I. Primary Lead Production Areas in the United States as Indicated on Figure 1[a]

State		District	County or Counties	Production (short tons)[d] 1968	1970
Arizona	1[b]	Glove	Santa Cruz	1,704	367
California	2	Death Valley	Inyo	4,001	1,674
	3	Death Valley	Inyo		
Colorado[c]	4	Creede	Mineral	19,778	20,304
	5	Ouray	Ouray		
	6	Butte	Gunnison		
	7	Gilman	Eagle		
	8	Rico	Delores		
	9	Silverton	San Juan		
Idaho	10	Page	Shoshone	54,790	59,667
	11	Kellogg	Shoshone		
	12	Clayton	Custer		
	13	Wallace	Shoshone		
	14	Mullan	Shoshone		
	15	Osburn	Shoshone		
	16	Burke	Shoshone		
	17	8 Miles west of Hailey	Blaine		
Illinois	18	Rosiclare	Hardin	1,467	1,566
	19	Rosiclare	Hardin		
Kentucky	20	Marion	Marion	--	--
Missouri	21	Higdon	Perry	212,611	432,576
	22	Magmont	Bent		
	23	Ellington	Reynolds		
	24	Flat River	St. Genevieve		
	25	Bonne Terre	Iron		
	26	Bonne Terre	Reynolds		
	27	Bonne Terre	Washington		
Montana	28	Butte	Silver Bow	1,870	1,502
	29	Elliston	Powell		
	30	Boulder	Jefferson		
	31	Dillon	Beaverhead		
	32	Philipsburg	Granite		

TABLE I. (Cont.)

State		District	County or Counties	Production (short tons)[d] 1968	1970
Nevada	33	12 Miles from Gabbs	Nye	863	494
New Mexico	34	Vanadium	Grant	1,363	3,758
	35	Hanover	Grant		
	36	Bayard	Bayard		
New York	37	Balmat	St. Lawrence	1,396	1,259
Oklahoma	38	Gordon	Ottawa	2,387	--
	39	Tri-State	Ottawa		
Utah	40	Mayflower	Wasatch	45,205	43,952
	41	Milford	Beaver		
	42	Bingham	Utah		
	43	Magna	Salt Lake		
	44	Ophir	Tooele		
	45	Lark	Salt Lake		
Virginia	46	Austinville	Wythe	3,573	3,379
	47	Ivanhoe	Wythe		
Washington	48	Metaline Falls	Pend Oreille	5,655	--
Wisconsin	49	Shullsburg	Lafayette	1,126	798
	50	Elmo	Grant		
	51	Mineral Point	Iowa		
Other States (Alaska, Kansas, Kentucky, Oregon)	52	--	--	1,367	7,449
Totals				359,156	578,745

[a]From Lutz et al.(6).
[b]Numbers designate areas in Figure 1.
[c]Keystone Mines Company recently announced a new plant located at Crested Butte, Colorado, for the production of silver, lead, and zinc concentrate capacity 300 tons/day (Chemical Engineering, April 1970, p. 126).
[d]1 short ton = 2,000 pounds.

TABLE II. Smelters and Refineries as Indicated on Figure 1[a]

State		City	County or Counties	S-Smelter R-Refinery
California	1[b]	Selby	Contra Costa	S & R
Idaho	2	Bradley	Shoshone	S & R
Indiana	3	East Chicago	East Chicago	R
Missouri	4	Herculaneum	Jefferson	S & R
	5	Glover	Iron	S & R
	6	Bixby	Bixby	S & R
Montana	7	East Helena	Lewis and Clark	S
Nebraska	8	Omaha	Douglas	R
Texas	9	El Paso	El Paso	S
Utah	10	Tooele	Tooele	S

[a]From Lutz et al.(6).
[b]Numbers designate areas in Figure 1.

TABLE III. Lead Produced by Smelting and Refining (S & R) and Introduced into Usage[a]

Company	Location of S & R Operations	1970 Production (short tons)
Amax-Homestake Lead Tollers	Bixby, Missouri	115,089
ASARCO	East Helena, Montana	225,968
Bunker Hill	Kellogg, Idaho	123,106
International Smelting and Refining	Perth Amboy, New Jersey	11,994
St. Joseph Lead	Herculaneum, Missouri	206,343
U.S. Smelting, Refining, and Mining	East Chicago, Indiana	29,988
Total		712,488

[a]From Yearbook of Metal Statistics, 1971(9).

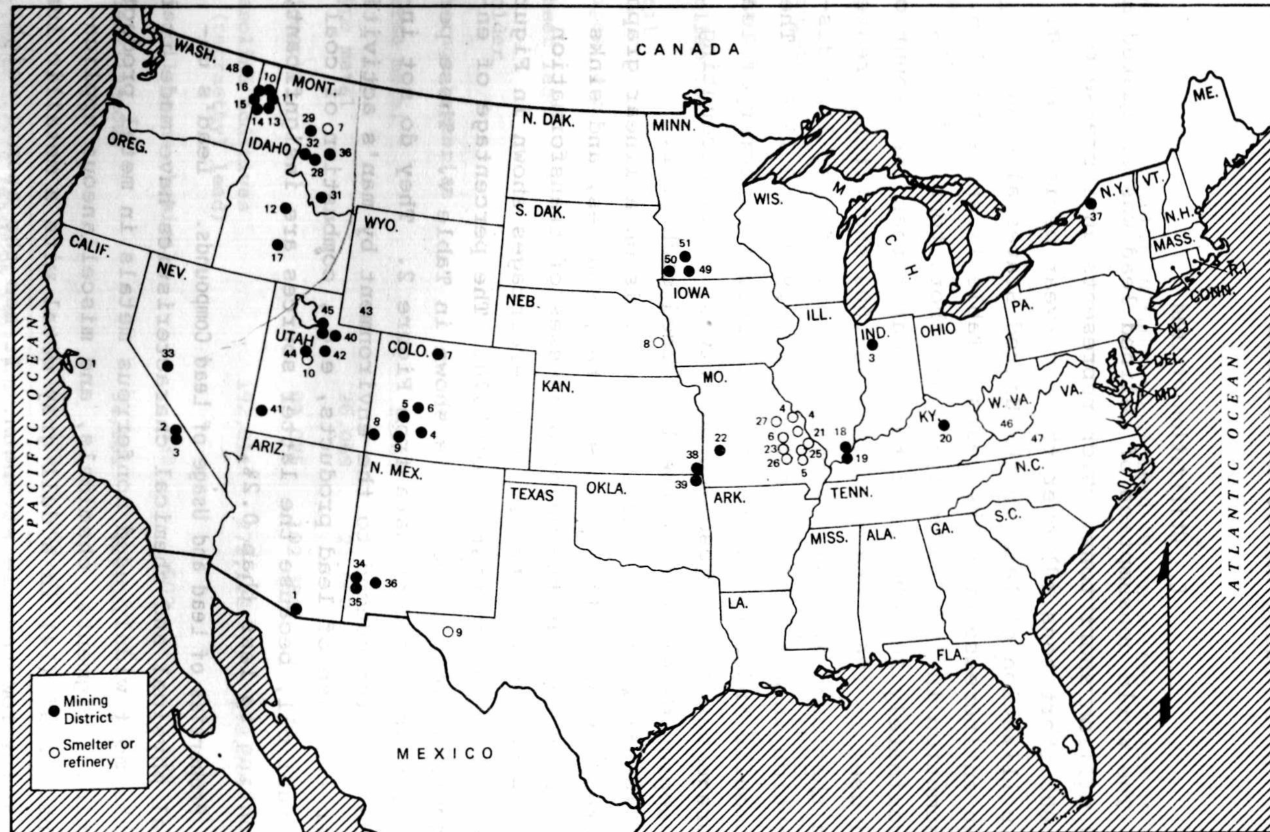

FIGURE 1. Primary lead production in the United States, [From Lead Industries Association, Inc. (7).]

C. Utilization of Lead

The world consumption of refined lead was estimated at 3.89 million short tons, which represents an increase of 650,000 short tons (8) over the five-year period 1966-70. The utilization of lead in the United States also has shown an increase over the years. Table IV shows the U.S. consumption in 1970 to be 1,360,552 short tons. This is approximately 200,000 short tons greater than the amount of lead used in 1963, and more than 900,000 short tons greater than that used in 1934. Table IV also indicates lead distribution in metal products for 1963, 1969, and 1970. The automobile industry is the largest product consumer of lead, (storage batteries, gasoline additives, etc.) accounting for approximately 60% of the lead used each year.

The flow of the lead in industry is on a linear graph, Figure 2, showing the various states, sources, and sinks of lead as well as the major processes of transformation represented by industries. The percentages shown in Figure 2 represent the statistics of 1970. The percentage of environmental lead by source is shown in Table V. These percentages are based on data from Figure 2. They do not include lead introduced to the environment by man's activities other than use of lead products, e.g., combustion of coal and fuel oil, because the latter sources are insignficant, amounting to less than 0.2%.

1. Properties of Lead and Usage of Lead Compounds. Lead's unusual physical and chemical characteristics have made it one of the most widely used nonferrous metals in metal products, coatings, pigments, chemicals, and miscellaneous applications. Lead (14) is a dull gray metal with a metallic luster and a low tensile strength. It has the atomic weight of 207.19 and a density of 11.35 grams/milliliter (g/ml) at 20°C (just below room temperature). This is about