The new lead belt in the forested Ozarks of Missouri

Lead industries, scientists and regulatory agencies work together to mine this resource while they solve environmental problems

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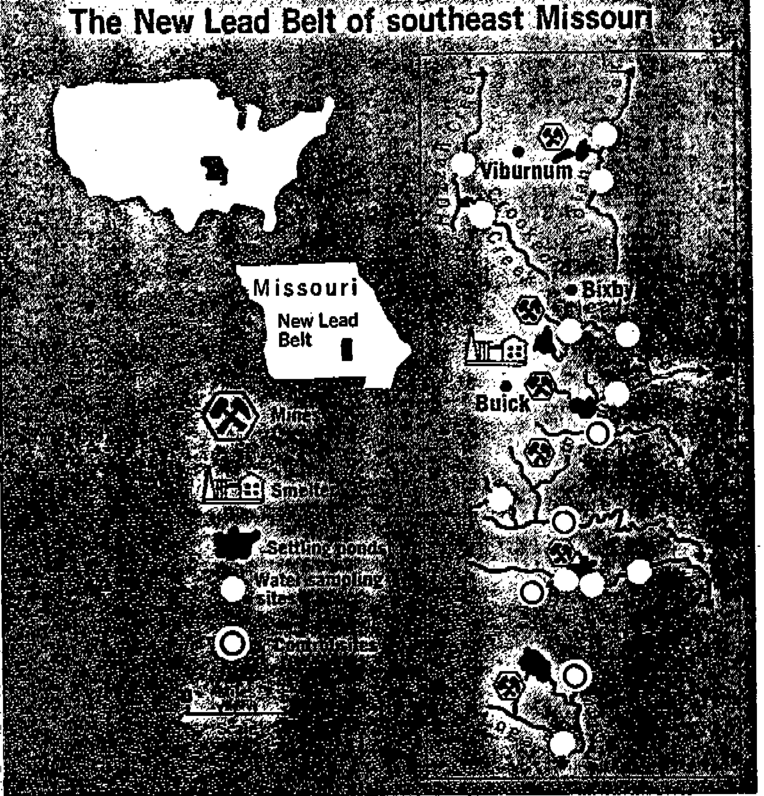
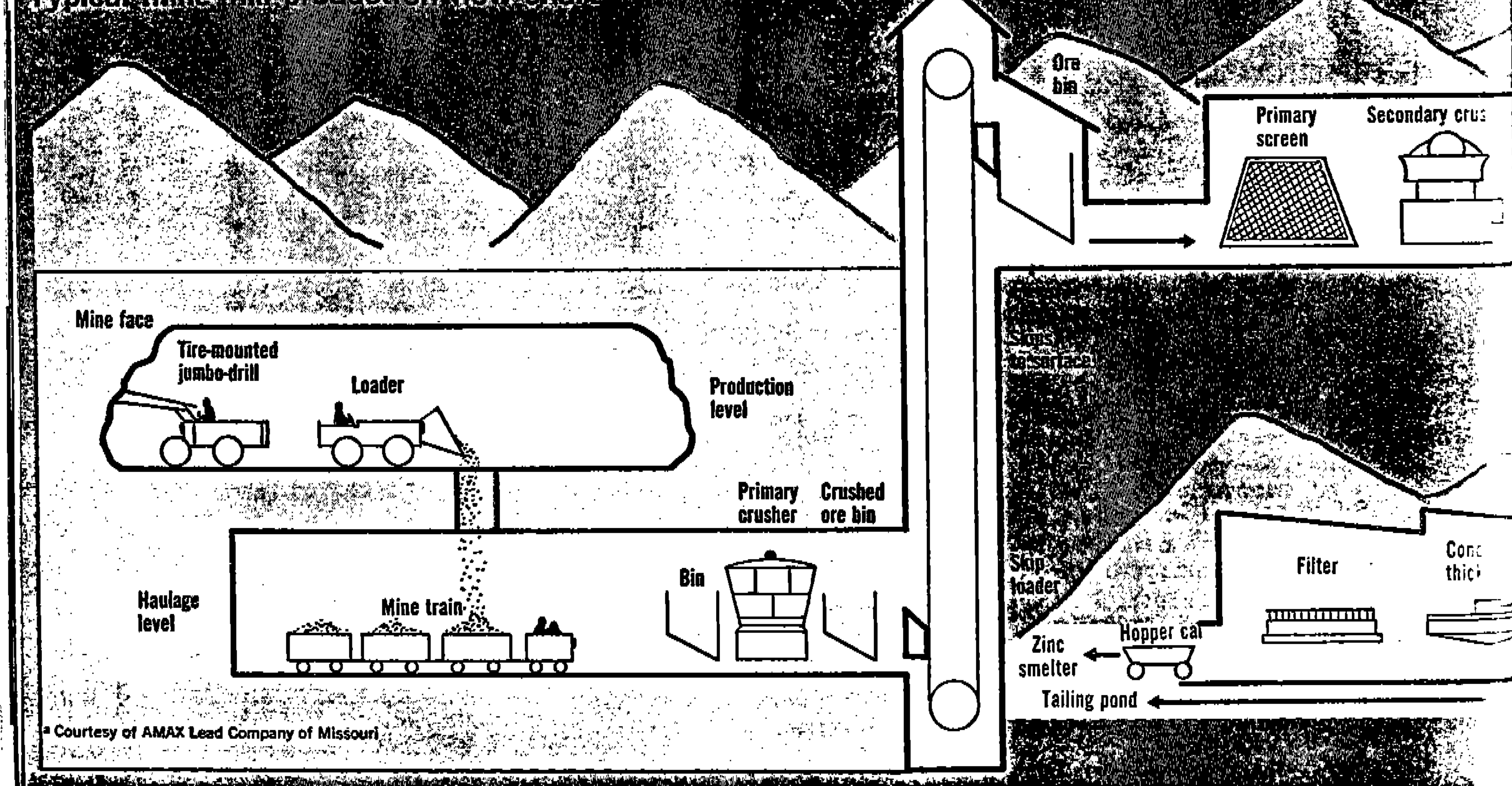
FIGURE 1
The New Lead Belt of southeast Missouri



FIGURE[a]
Typical mine-mill production flow chart



[a] Courtesy of AMAX Lead Company of Missouri

Lead, depending on its use or misuse, has been of increasing scientific and technological concern in the U.S. One approach to a better understanding of this necessary but controversial metal is to study the magnitude, distribution and impact of lead in the environment at the source of mining, milling and smelting. Presently, seven modern mines in close proximity to two lead smelters in the forested Ozarks of southeast Missouri are the largest source of lead in the world.

Since lead, zinc, copper, silver, cadmium and many other heavy metals are potentially hazardous when released into the environment in certain forms, they have been of considerable concern to governmental agencies, industry and the public at large. In response to this potential hazard, the National Science Foundation (NSF)-RANN's (Research Applied to National Needs) interdisciplinary research team at the University of Missouri has studied trace contaminants associated with the production of lead for the past six years. The research team has disseminated information to industries, regulatory agencies, the general public and the scientific and engineering communities as rapidly as it has become available, and in a form that could be practically applied to the user's need. From the inception of this research, it was a stated goal that the environment of this unique region not only be studied but improved, if possible, and that to accomplish this goal, all interested parties had to be actively involved. One of the most important benefits of this study was the demonstration that diverse interest groups could work together to develop common solutions to environmental problems. Even more importantly the experience in establishing such working relationships has been transferred to similar situations throughout the U.S. and the world.

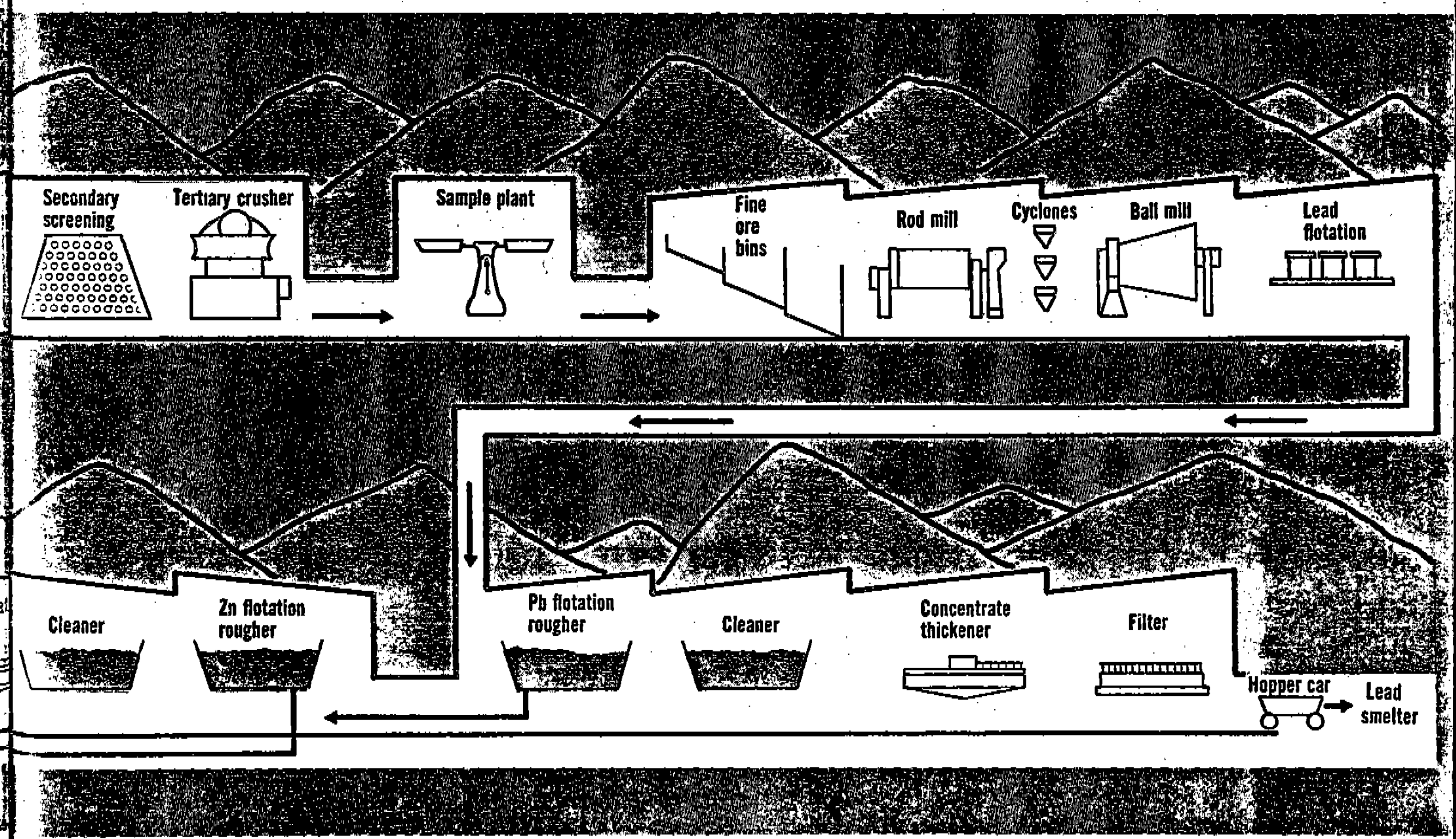
History

Since the early 1900's Missouri has been recognized for the production of lead. Lead in Missouri was first discovered by French developers as early as 1701 and mined from shallow surface deposits in 1720.

Between 1800 and 1900 some 25,330 short tons of lead were produced and in 1818 a lead smelter was established on the Mississippi River at Herculaneum. Additional lead deposits were discovered in 1840 near Joplin, Missouri, and from 1850 to 1860, three major lead and zinc mining districts were developed. By 1902 Missouri had become the leading mine producer of lead in the U.S. and has maintained that position until the present, with the exception of 1962 when strikes decreased production.

Increasing production of lead occurred during the period of 1906 to 1918 with the largest amounts being produced during World War I. Most of this production was from the "Old Lead Belt" in Madison and St. Francis counties, with the St. Joseph Lead Company (now St. Joe Minerals Corporation) being the main producer. However, in 1943 St. Joe realized the importance of finding new ore reserves to replace those that were being rapidly mined out and embarked on an extensive exploration program outside the older established areas.

In 1955, St. Joe discovered a rich lead-zinc deposit that extended approximately 40 mi due south from Viburnum, Missouri. Grades of ore varied from low to very high, but have



since proven to be of higher quality (8–12%) than initially forecast. Most of this discovery was on federal lands (the Clark National Forest), which meant that planning concerned with the development of a major mining industry within the multiple-use program of the National Forest had to be done. This lead-rich area was called the "Viburnum Trend" or "New Lead Belt" of Missouri. The geographic location of the New Lead Belt with its stream-drainage pattern in relation to the mines and one lead smelter is shown in Figure 1.

Economic significance

The economic significance of this unusual mineral district is just being realized, and promises to offset predictions that additional lead mineral reserves need to be discovered to meet resource demands during the balance of this century. The Third Annual Report of the Council on Environmental Quality emphasized that the modern low-cost lead producers in southeast Missouri would be able to maintain peak production and be able to absorb pollution control costs, while high-cost lead producers in other states might be unable to raise the required capital for necessary pollution control and would be forced to close.

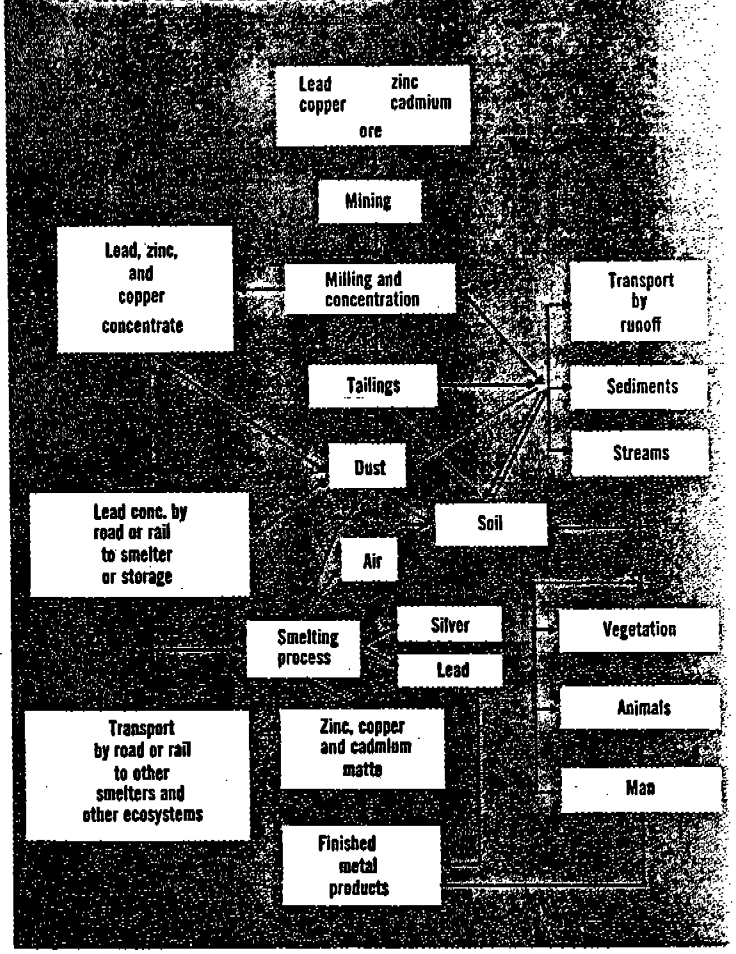
In 1970, the New Lead Belt ranked first in the world; the area produced 432,576 tons of lead ore. The area has continued in its role as the major lead producer, and has established new records in 1974 with the estimated lead production of 576,300 short tons of metal, or approximately 85% of the total output mined in the U.S. Zinc, copper and silver production also increased as co-products and the combined value of these four metals was estimated to have a value of $352 million in 1974.

Technology

Efficient and modern engineering designs have been incorporated into the mines, mills, and smelters servicing the area.

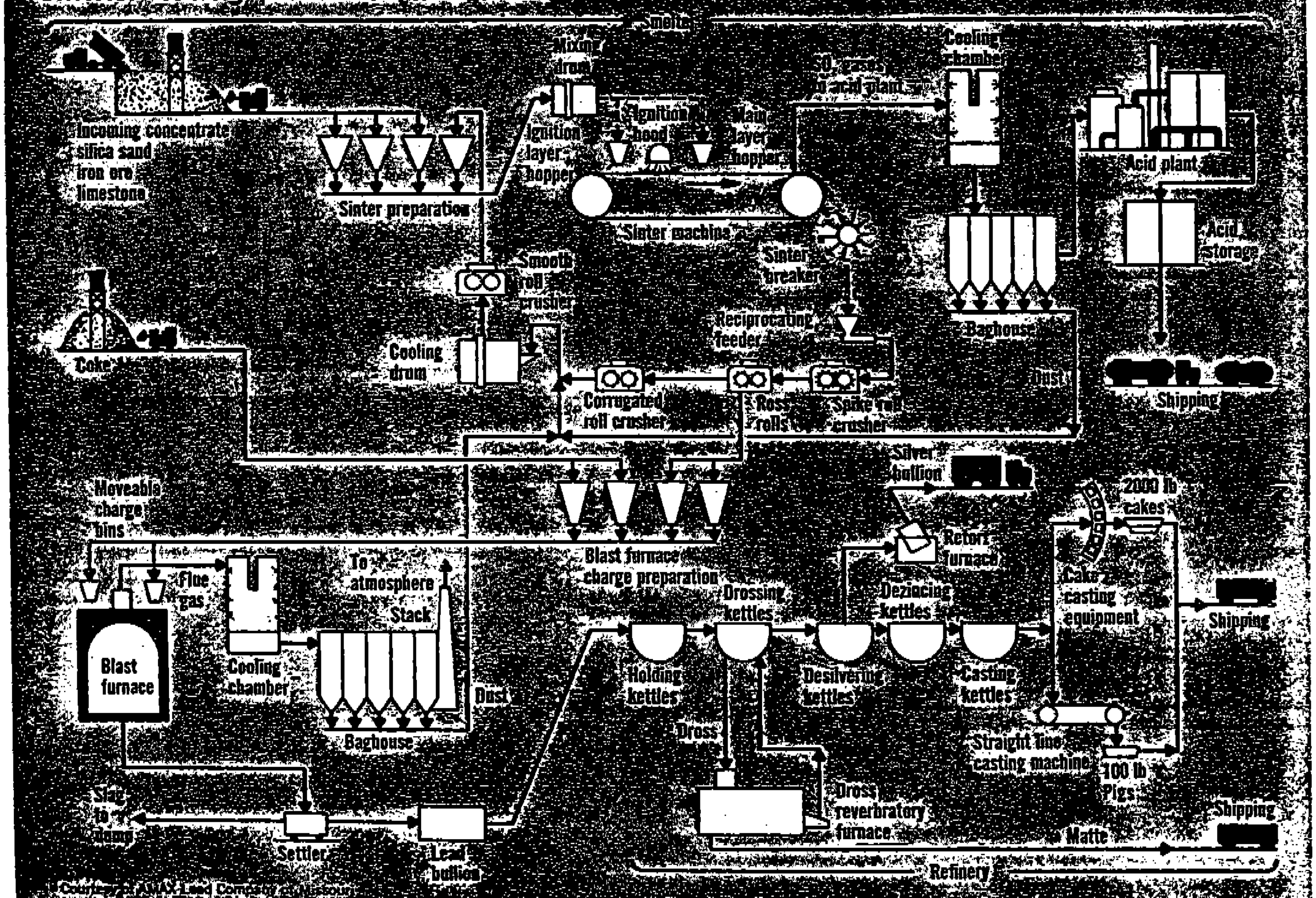
FIGURE

Sources of trace metals in the environment of the New Lead Belt area



FIGURE

Smelter-refinery production flow chart



Galena (lead) is the principal ore mined with lesser quantities of sphalerite (zinc), chalcopyrite (copper) and silver recovered as economic co-products.

The lead ore is disseminated throughout the mostly dolomite Cambrian Age Bonneterre Formation, at depths ranging from 700–1200 ft (213–366 m). Since the producing formation is also a good aquifer, some mines must employ constant pumping to prevent flooding. This inflow of water has reduced mine dust as a potential problem, but mine water pumped to the surface contains an appreciable amount of fine galena and other trace metals as well as associated spillage from equipment and maintenance operations.

Generally, mines are worked by the standard "room and pillar" method. The back ore is drilled and shot in one or two passes followed by haulage to a gyratory crusher via large diesel loaders or locomotive-drawn railcars. After primary crushing underground, the ore is hoisted to the surface in a skip. Most of the mines also have two shafts—one for men and equipment and the other for ore hoisting and charging of the ore bin at the mill. Automation is a key factor and the most advanced mining equipment and technology are used at the mines.

Part of the water pumped from the mines is utilized as process water for the milling procedure in which chemical reagents are added during the flotation circuit to separate the lead, zinc, or copper from the finely ground rock or gangue. The flotation reagents usually consist of chemical collectors, frothers, depressants and activants.

The lead and zinc (and sometimes copper) minerals from the flotation process are pumped into thickeners where the concentrate settles leaving the water, excess flotation reagents, and the colloidal and supracolloidal minerals as milling effluent. The concentrate is vacuum dried by various methods and then transported to smelters for the final conversion to metal. A typical mine-mill production flow chart is shown in Figure 2.

The water and tailings wastes from the mine and mill operations are discharged into settlement and treatment ponds. The tailings pond dams are usually constructed to tails (generally less than 200 mesh in size) materials from the ore concentration process; the tailings are separated into fine and coarse fractions by cyclones (centrifugal separators). Once the dams have been initially constructed, the tailings and other liquid wastes are introduced upstream from the dam until the lagoon is effectively filled. The lagoons are designed to settle out residual tails and biologically degrade any spent organic reagents discharged from the milling process.

Figure 3 illustrates a typical smelter-refinery production flow chart for a modern lead smelter with several types of emission controls such as an acid plant, baghouse, atmospheric stack and other modifications. These operations must be carefully monitored so as to control the emissions of lead and other trace metals.

Environmental impacts

This rapid industrial development in a sparsely populated, rural forest region has caused various forms of lead, copper, zinc, cadmium and other trace metals to be released into a formerly "pristine" ecosystem. Because of this abrupt change, the mining district offers a unique area for studying the impact of trace metals and developing improved techniques to control detrimental effects. In addition to studies made in the New Lead Belt area, soil and vegetation investigations have been made near the ASARCO Lead Smelter at Glover, Missouri, as well as along the haulage roads used to transport lead concentrates from the mines to the smelter.

Research has been done to determine background values, to establish natural baselines and to evaluate the lead mining and smelting industry as a source of trace metals in the environment. Sources of trace metals in the environment were found to be associated with

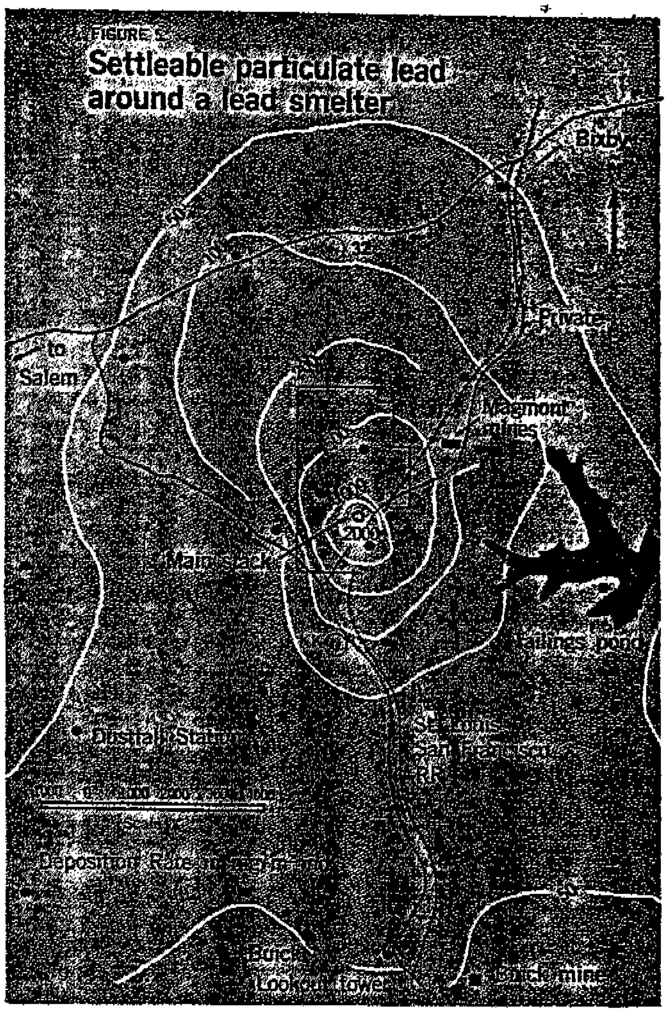


FIGURE 5: Settleable particulate lead around a lead smelter

- the mining-milling operations with problems of grinding, concentrating and transporting ores and disposal of tails along with mine and mill wastewater
- the smelter-refinery process with problems of concentrate haulage, storage, sintering, refining, atmospheric discharges and blowing dust. Figure 4 depicts the possible sources of trace metals in the environment of the New Lead Belt area.

Data utilization

The air quality data collected during this study has been used as the basis for negotiating differences in standards set by the Air Conservation Commission in the Missouri Department of Natural Resources and the U.S. EPA. The data were selected not only for their uniqueness but also for their rigid neutrality in arbitrating differences among agencies, industries, and the populace.

The information on heavy metal transport from fugitive sources has resulted in improved procedures for controlling problems at the smelters and at the mine-mill complexes of the region. Ore concentrates are stored under roof or sprinkled with water to prevent blowage. The area around the AMAX Smelter has been paved (at a cost exceeding $1 million) so that metal-rich dust can be washed into containment ponds and recycled through the smelting facilities thereby preventing resuspension by truck traffic through the area. Figure 5 illustrates the distribution of settleable particulate lead around one smelter that has been used by the industry as a model in developing improved control procedures and equipment.

Information on the efficiency of the various smelter emission control devices has been used to develop plans for improving emissions. The implementation of improved pollution control technology has resulted in the expenditure of millions of dollars for capital improvements. For example:

- A "high efficiency" mist eliminator and additional cooling equipment were installed to the acid plant for increased acid production, improved sulfur recoveries and reduced sulfur dioxide emissions.
- Four permanent sulfur dioxide ambient monitoring stations were installed at a cost of $50,000 and a fifth station is planned. Whenever the sulfur dioxide ambient level at any station exceeds the Missouri 1-hr ambient standard (0.25 ppm) for more than 10 minutes, the sinter-acid plant is shut down.
- A continuous sulfur dioxide stack analyzing system was installed at an estimated cost of $20,000.
- The acid plant baghouse has been replaced with a hot electrostatic precipitator at an estimated cost of $1 million.
- Two dams were constructed to catch and settle all stormwater runoff from the smelter plant area at a cost of $50,000.
- Improved baghouse maintenance and operation were developed and a well-qualified, full-time, inhouse, environmental group was established to monitor operations and work with agencies and researchers on effective pollution control procedures. Other air quality control applications have been developed from research recommendations by Ernst Bolter, Kris Purushothaman, Delbert Hemphill and Ivon Lowsley of the RANN-University of Missouri interdisciplinary team.

Pertinent studies

Soil and geochemical research studies led by Ernst Bolter have indicated the extent of the geochemical anomaly surrounding mines and lead smelters. This information, coupled with air quality and other data, has shown the need for controlling fugitive emissions. The U.S. Forest Service is considering the possibility of establishing a wilderness buffer area immediately adjacent to one smelter to eliminate some of the possible hazards to animals through the accumulation of metals in vegetation and soil.

Studies have also indicated that the tailings dams are sources of windblown lead and zinc; several mining and milling companies have responded to this problem by planting appropriate native vegetation to hold fine materials in place.

Evidence also exists that the accumulation of heavy metals in the soil and leaf litter may be a more sensitive and practical indicator of cumulative pollution than current air pollution technology methods. Methods of illustrating these zones through the use of computer plotted isopleths based on soil analysis are illustrated in Figure 6.

Studies of the interrelationship between humic acids and heavy metals have also opened a number of new possibilities for treating heavy metals-containing wastes from industries other than the mining industry. Interesting results have been reported by Ernst Bolter (of the interdisciplinary team) and research continues in this area.

Data collected from the long-term water quality studies were utilized to adjust the Missouri Clean Water Commission Effluent Guidelines for heavy metals; the ratio of actual to allowable effluent concentrations was adjusted from 1 to 2.

In another case, a biological meander treatment system was developed through cooperative efforts between one company and researchers that has been demonstrated to be a superior mine-mill waste treatment technique. The system has been found to be economical, effective, and has decreased the incidence of excessive algal growth and heavy metals buildup in receiving streams. Since once-affected streams have recovered through the utilization of this improved control technology this technology is now considered by some mining engineers to be a practical and economical solution to certain stream problems.

FIGURE 6

Lead (ug/gm dry wt.) in upper layer of partly decomposed leaf litter on the ground surrounding a lead smelter

Research on the algae and stream macrofauna by Nord Gale and others of the interdisciplinary team has indicated that lead is not biologically concentrated by aquatic organisms. The possibility of bioaccumulation up the aquatic food chain has long been a concern of state agencies and the public who use this recreational area. Studies have also demonstrated that the inorganic nutrients in the mine water are contributing factors in producing undesirable algal blooms in receiving streams; improved treatment schemes are being further refined to eliminate these problems.

Interestingly enough, a stream pollution incident was produced by one lead smelter attempting to meet an OSHA standard that resulted in serious amounts of heavy metals entering the aquatic environment when the plant area was washed down to eliminate dust. This incident has stressed the need for continued vigilance on the part of industry in handling these metals.

It has also been found that heavy metals are washed from the soil into the streams and carried therein as suspended solids. These findings have resulted in the mine-mill complexes developing more efficient solids-retention devices. Research has also shown that stream velocities of this region are too rapid for heavy metals to settle at dangerous levels in the sediments. Most of the area's streams drain into Clearwater Lake and metal-containing sediments have not been found to have accumulated to a significant level over the past eight years.

Studies of the leachates from naturally and artifically contaminated soils have shown that, under present conditions, no hazard exists for the possible heavy-metal contamination of the water table resulting from the downward percolation of rainfall. Evidence has been found, however, that humic acids leached from the forest litter layer can mobilize lead and other heavy metals dramatically, and the long-term effects of this litter layer on heavy metal mobility requires further investigation.

Research on vegetation has been coupled with data from the geochemical and air quality studies to show that the ore haulage roads and railroads are another source of heavy metals emissions. As a result, planning is underway to retain all metal concentrates within some type of transport container, or at least under cover.

Dramatic research experiments have shown that lead can not only be removed from the soil and translocated to plant leaves, but that certain plant leaves can take up lead from aerial sources and translocate it to its roots. These findings have raised questions about allowing certain animals to graze close to the sources of heavy metals emissions. Research by Jim Pierce and Roy Koirtyohann of the interdisciplinary team has indicated that deer from the New Lead Belt region have a higher level of lead in their leg bones than deer from control areas; but as yet no clinical symptoms have been observed. This information has been used by the Missouri Department of Conservation and the U.S. Forest Service in the development of management plans for future recreational uses of this region.

Remote sensing and data handling research by William Tranter and Jerry Sandvos of the interdisciplinary team have developed new techniques for rapidly evaluating biological activities in the mine-mill treatment ponds. This has been of great value to the research team, and computer-aided techniques are being developed to improve currently existing aerial surveillance and optimal sampling programs.

Results from the remote sensing studies are additionally being utilized by the University of Kansas in a collaborative study for NASA. This project has also developed improved methods to permit ground truth correlation with NASA's ERTS remote sensing program, which allows large area maps to be made at minimum cost for use by industry and governmental agencies.

Dissemination of data

Selected samples from this multi-disciplinary study may be utilized for the National Environmental Specimen Bank System (NESBS) proposed by the National Academy of Sciences Subcommittee on the Geochemical Environment in Relation to Health and Disease at the May 1973 workshop at Capon Springs, W. Va. Pertinent environmental samples from the project should be stored as a base for determining long-term changes in environmental quality.

Information and knowledge gained through this study have been presented to appropriate user groups for the development of policies and implementation of improved pollution abatement technology to control trace contaminants in the environment. Throughout this program, research information and techniques have been exchanged with Colorado State University and the University of Illinois, which are participating in other aspects of lead and trace metal research under the NSF-RANN Trace Contaminants Program.

A collaborative effort between the University of Missouri and Oak Ridge National Laboratories is underway to determine if realistic models can be developed and tested under field conditions. Practical models would be of considerable value to both industry and regulatory agencies in predicting and controlling possible effluent or gaseous emissions from sources in the lead-zinc industries.

Data utilization of the lead studies performed under grants from the NSF-RANN Trace Contaminants Program have been beneficial to industries, regulatory agencies, the scientific community, and the interested general public. Research findings have been applied by industries to the development of improved pollution technology, both controls and monitoring. Federal and state regulatory agencies have utilized research data for the development of more effective standards and for long-range planning to protect the health of people and their environment. The practical, common sense working partnership developed in this NSF-RANN Project—with the University of Missouri serving as an unbiased intermediary between agencies and industry—has allowed environmentalists to work with industrial and agency representatives to define and resolve problems for social and economic benefits. This unique partnership has been called a model for environmental cooperation, and was cited by the Zuckerman Commission Report to the United Kingdom of Mining and the Environment as being beneficial to the local community and its surroundings.

In this time of energy conservation, increased resource needs, scientific and technologic advances and environmental awareness, a practical, cooperative approach among industry, regulatory agencies, decision-makers, the engineering and scientific communities and the general public must be maintained if needed mineral resources are to be produced without a detrimental effect on the environment.

Additional reading

Wixson, B. G., Bolter, E., Gale, N. L., Jennett, J. C., and Purushothaman, K., "The Lead Industry as a Source of Trace Metals in the Environment," in Cycling and Control of Metals, U.S. Environmental Protection Agency, National Science Foundation and Battelle Memorial Institute, National Environmental Research Center, Cincinnati, Ohio, 11 February, 1973.

"Lead, a Four Letter Worry." 5 minutes, sound and color motion picture available in 16 mm film. RANN Document Center, Office of Intergovernmental Science and Research Utilization, National Science Foundation, 1800 G Street, N.W., Washington, D.C. 20550.

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J. Charles Jennett *is chairman and associate professor of civil engineering at Syracuse University. Dr. Jennett was formerly co-director of the NSF-RANN-supported trace contaminants project at the University of Missouri-Rolla.*

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