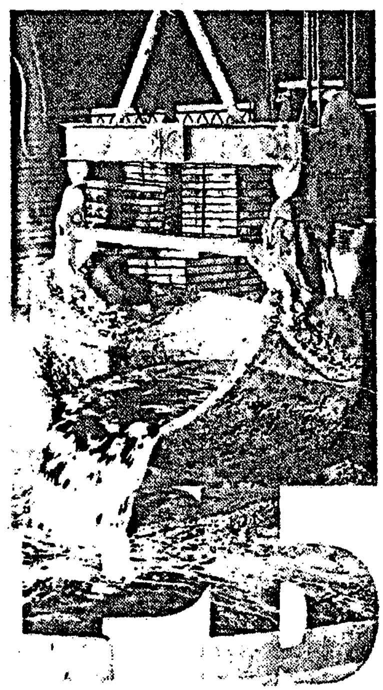
Lead: the debate goes on, but not over science

Research on the extent of lead contamination of the modern environment and on the health effects of low levels of lead has done much to remove scientific uncertainty and to shift debate from the scientific to the political realm

It is two millenia since the first description of lead poisoning appeared, two centuries since Benjamin Franklin wrote on the effects of lead, half a century since lead paint was tracked down as the cause of lead poisoning in children. "Why," asks Herbert L. Needleman of the Harvard Medical School, "does the problem of lead continue to be debated? And why is the orderly process of decreasing lead in the human environment slowed in the face of what many consider an overwhelming body of facts documenting its toxicity at low dose?"

The answer, says Needleman, is no longer scientific uncertainty, but economics and politics. On one side are six government agencies charged with regulating and studying lead. They face an enormous task. Lead appears in food from the solder used on cans; in water from the lead pipes used in older plumbing; and in air from lead additives used in gasoline, from the dust of old lead paint and putty, and from the initial smelting of lead ore that makes lead available for all its uses. Several of those agencies are playing a game of musical chairs, each trying to pass the responsibility to another by showing that the source of lead exposure it regulates is insignificant compared to the others (*Chemical and Engineering News*, June 23, 1980, p. 23). On the other side is an industry that is fighting for its very existence, and will fight all the harder as more take up the cry of Clair C. Patterson, a geochemist at the California Institute of Technology: "It is intrinsically wrong to mine and smelt millions of tons of a highly toxic, poisonous substance such as lead each year and disperse it within human environments."



Two controversies

Research that in the last few years has done much to settle two long-standing scientific controversies concerning lead in the environment has in particular made it clear that the continuing debate hinges on politics, not science. The first, over the extent of contamination of the contemporary environment, has been all but put to rest by Patterson's work; he has shown contamination of the oceans of the Northern Hemisphere 10-fold over prehistoric levels; the atmosphere, 50-fold; the Greenland ice cap, 300-fold; and most Americans' bodies, 600-fold. Most significantly, he has demonstrated that conflicting results obtained by others were the result of contamination of samples and laboratory equipment, leading to analytic errors of as much as three orders of magnitude in the numbers they obtained for prehistoric levels.

The other controversy—the effects of low levels of lead—while not put to rest, is at least not thrashing about in the quagmire of a few years ago. This is largely the consequence of a carefully controlled epidemiological study by Needleman that showed poorer performance and more behavioral problems among children with elevated, but subacute, levels of lead in their bodies.

Natural or industrial?

Patterson's work is the climax of a story that began in 1924, a story of analytical chemistry with a touch of imaginative detective work. In 1924, J. C. Aub et al. published a paper in the *Journal of the American Medical Association* which reported that lead did not occur naturally in humans; only workers improperly exposed to industrial lead were contaminated. Improved analytical techniques allowed R. A. Kehoe to refute this claim a decade later; he showed that lead occurred at low levels even in the blood

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and excreta of typical adults.

His facts were correct but his conclusion was not. He believed that the levels he detected in typical adults were natural, not the result of industrial activity. This view survived intact for three decades. Even by the mid-1960s, the prevailing medical opinion was that no more than one-half of the lead in humans was of industrial origin.

It was Patterson's early work on lead contamination of the environment that unleashed the controversy. "Patterson claimed that humans were contaminated with industrial lead by a factor of 100," explains Robert W. Elias of Virginia Polytech. "This estimate was based on his estimate of lead contamination in the environment. It has taken almost 20 years to verify Patterson's numbers, and he was right."

Patterson was right because he takes elaborate precautions to prevent contamination of his samples and his laboratory by the elevated levels of lead that are omnipresent in the modern environment. The interior of his lab is lined with plastic; an air-lock and pressurized ultra-clean air prevent outside contaminated air from entering; and his reagents are cleaned of lead contamination within the lab.

His precautions—and his use of the most sensitive analytic technique for lead, isotope dilution mass spectroscopy—have given him the edge needed to detect the true, minute quantities of lead occurring in samples that reflect the prehistoric environment. And he has shown time and time again that conflicting results obtained by other workers are the result of sample contamination and inadequate analytic techniques.

The most recent instance was data that questioned Patterson's analysis of deep, ancient arctic ice. Patterson's group had found that 3000-year-old ice contained only 2 ng lead/kg, compared with 200 ng/kg at present.

Three other groups subsequently reported finding prehistoric levels to be much higher, in fact nearly the same as present levels—findings that suggested Kehoe was right, that current typical levels of contamination are natural and not the result of industrial activity.

But in a paper to be submitted to *Geochimica et Cosmochimica Acta,* Patterson and a graduate student, Amy Ng, report that their analyses of the ice cores used by the other groups revealed considerable contamination of the cores during drilling and handling. Lead concentrations at the center of the cores turned out to be less than a tenth of the values reported. Concentrations on the outside of the cores were six orders of magnitude over the true uncontaminated values.

Patterson's group has dug out other obscure records of the ancient environment—pond sediments, deep ocean water, bones of prehistoric Peruvians—and all have confirmed his basic contention: Industrial lead is ubiquitous in the modern environment at concentrations orders of magnitude above natural levels.

The Peruvian bone data has a special significance because it provides a direct measure of the natural level in humans, some two to three orders of magnitude below present typical levels. The data also lend concrete support to the "biopurification" theory that Elias has used to estimate natural levels in humans and other organisms.

Elias explains that nonpollutant trace metals such as barium and strontium are increasingly purified with respect to calcium as they move up the food chain. Calcium is essential to the workings of all living things, and they therefore actively concentrate calcium at the expense of the other trace metals. By analogy, the ratio of lead to calcium should drop as well in going from plants to herbivores to carnivores. Elias's predicted value for natural lead in humans so obtained is within a factor of two of the value found in the Peruvian bones.

Politics and pride

In the face of this overwhelming body of evidence, resistance to Patterson's findings can be attributed largely to politics and professional pride—no one likes to be told that his analytic technique is off by a factor of 1000, and Patterson hasn't balked at stepping on toes. Patterson, who was reached in American Samoa where he is doing field work, believes it is a matter of time for his results and methods to sink in:

"Knowledgeable and competent scientists who understand the significance and who are aware of the quality and integrity of the work of my colleagues and myself are in uniform agreement. A large number of applied chemists have made an enormous number of measurements of environmental occurrences of lead that are in error by many orders of magnitude. This is a fact which is not controversial. The problem is the length of time it will take for applied chemists to recognize this fact.

"Here at the U.S. NOAA Air Resources Laboratory in Pago Pago, American Samoa, I and my colleagues are determining the input flux of lead to the South Pacific. One of the parameters we measure is the concentration of lead in the easterly trade winds. It is difficult to properly collect filtered samples of such air that are scientifically significant because of interference by local sources of industrial lead contamination. So elaborate precautions must be taken to properly locate the air collector, which can be operated only a fraction of the time, under suitable meteorological conditions. During the past week, we operated our air filters only for five hours.

"During this same period, an air filter device placed nearby, but at a scientifically meaningless and totally unacceptable location, droned on and on 24 hours a day for days on end, collecting local lead pollution on filters that had been packaged and handled in the most crude and unacceptable fashion. In past years, these filters were sent to the U.S. National Health and Safety Laboratory of the Department of Energy. And their mindless, meaningless analytic results which have been published as reports of lead in air at remote locations typify the quality and significance of most of the large amount of environmental lead data now being collected and which will continue to be collected and published for some time to come."

Patterson's case does not end with his showing the analytic errors of others. He believes that the extent the modern environment is contaminated with lead is proof itself that we must stop the further mining and smelting of lead. And his argument takes a striking form when he points out that we have already increased our dietary intake of lead 100 times over natural levels—and that a further increase of a factor of only five brings us into the level of acute toxic effects. The "engineering approach," which demands subacute effects to be demonstrated before they are believed, ignores the extent of contamination, he says. No other metal may be increased in the diet by a factor of 100 without deleterious effect.

But not everyone buys this conclusion. The Food and Drug Administration, which has responsibility over canned foods, continues to use the typical levels of lead in canned foods as the reference point. When Patterson, in a paper published in *Science* last year, showed that tuna packed in lead-soldered cans is contaminated 4000-fold over fresh raw tuna—and that, once again, analyses of fresh tuna by others (including the FDA) came up with values 1000 times too high—FDA called it a "meaningless academic exercise."

"For the quantities of lead that are

found in these food samples, you don't need the kind of laboratory setup that Dr. Patterson has," says Kathryn R. Mahaffey, assistant to the director of FDA's division of nutrition.

Patterson calls this circular bureaucratic reasoning. "We have proved that they made 1000-fold errors in the determination of lead in raw tuna. Their response to this disclosure of their flagrant ineptitude is that the FDA is required only to correctly determine when lead concentrations increase above typical levels of about a half a part per million in canned tuna fish." Patterson insists that the reference point is not that half a ppm, but the natural levels, 1000 times less.

Subtle effects

But even while Mahaffey argues that "the assertion that the level of lead in the food supply causes health effects is not proved" and takes Patterson, a geochemist, to task for venturing into biology ("One thing that's important for scientists to recognize is that there are limits to their expertise"), she is convinced that progressively more subtle health effects of low-level exposures to lead will be indentified. This is the second issue, really the other side of the coin of the environmental contamination issue, and one which has also seen considerable progress in the last few years.

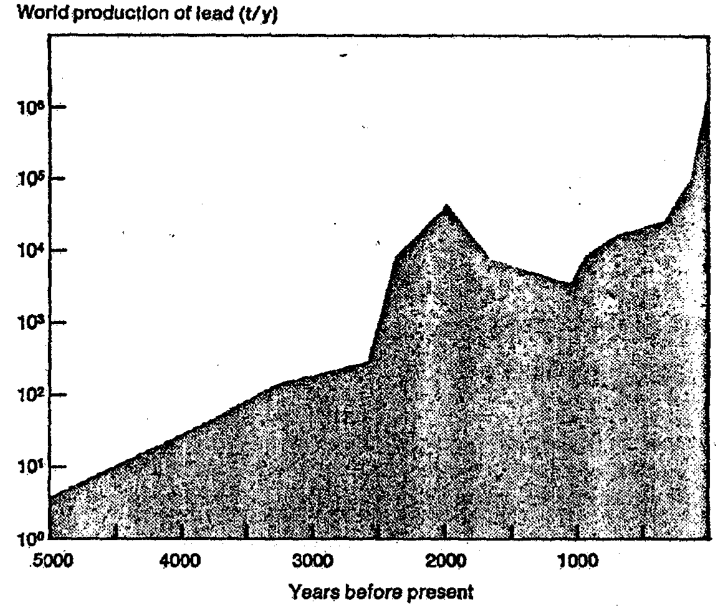
Spearheading that progress is an epidemiologic study by Needleman of some 2000 school children in the Boston area. His principal finding: "Lead in children at levels below that which bring them to a doctor are dangerous to their brains."

Children are particularly sensitive to lead. They absorb 30–50% of ingested lead, as opposed to the 5–10% that adults absorb. The acute effects of lead poisoning—constipation, vomiting, anemia, swelling of the brain, palsies, and eventually death—are well documented. Needleman set out to document more subtle effects that he believed showed up at subacute exposure levels—behavioral problems, poor intellectual performance, short attention span.

But epidemiology is an inexact science. Even studies that look for acute effects, such as lung cancer, are plagued with uncertainty. It is not unusual to find as many different results as there are epidemiological studies on a given subject. The subtle effects that Needleman was looking for make the problem all the harder.

He set out to design a study that would answer the objections leveled at previous studies of the subtle effects of lead, studies that are a morass of in-

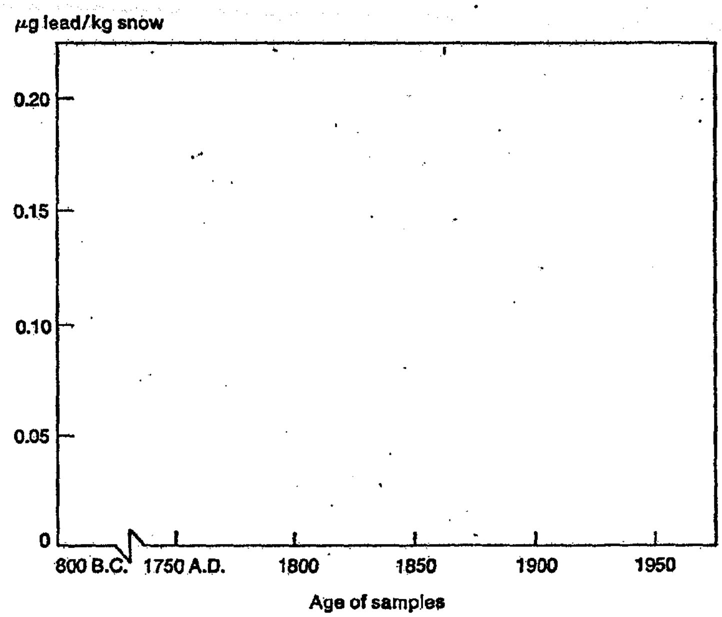
Increasing lead production...



Man began releasing lead to the environment with the discovery of cupellation, the process of separating silver from base metals including lead. Note that the vertical scale is logarithmic.

Source: National Academy of Sciences, "Lead in the Human Environment"

...and environmental accumulation



Samples of snow from the Greenland ice cap show the increasing contamination of the environment with lead.

Source: C. Patterson, California Institute of Technology

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conclusiveness. He identified four specific problems:

- Poor markers of past exposure. The almost universally used marker of exposure, blood lead concentration, reflects current exposure only.
- Ascertainment bias. Subjects who agree to participate in a study may differ markedly from those who refuse.
- Weak measures of outcome. Tests of behavior and performance are often limited or insensitive.
- Confounding variables. Factors other than lead exposure may affect the outcome.

Needleman used lead concentrations in lost primary teeth—lead accumulates in teeth as in bone—as the marker of lifetime exposure, and he collected teeth from 70% of the children studied. A variety of double-blind performance tests (IQ, reaction time, sentence repetition) were used along with teachers' ratings of the children's classroom behavior ("distractable," "impulsive," "does not follow instructions") to measure the outcome. And after separating children into high-lead and low-lead groups, Needleman looked at some 30 nonlead variables (medical histories, race, sex, parents' income, parents' attitudes towards school, mother's number of pregnancies) and controlled for five that he found to differ significantly between the two groups.

"High-lead children were found to be significantly less able on a number of performance measures," Needleman says. "High-lead subjects were also significantly more likely to be reported as disordered in their classroom behavior." The high-lead group had a four-point lower mean IQ than the low-lead group. And when Needleman separated the children into six groups according to lead levels, he found a continuous dose-response relationship on each of the items of the teachers' ratings. There appeared to be no threshold.

Insensitive or negative?

The resistance to Needleman's findings may once again be more a matter of politics than science. The lead industry continues to cart around results of studies that Needleman and others call poorly controlled and insensitive; these show no correlation between lead exposure and performance of children. At the recent annual meeting of the American Association for the Advancement of Science, Jerome F. Cole of the International Lead Zinc Research Organization (ILZRO), an industry-supported group, gave considerable attention to one of these studies, carried out among children who had lived near a lead smelter in El Paso. Cole quoted from the findings of a committee set up by the Society of Occupational and Environmental Health to evaluate that work: "In summary, the committee concluded, reports and data made available in these studies of El Paso have not clearly demonstrated psychological or neurological effects in the children under study."

Yet Cole admits in passing that the committee also found that the studies were not powerful enough to demonstrate the absence of health impairments—which is the very essence of why negative results from insensitive studies are of little value. And that is Needleman's key message: A negative result does not simply cancel out a positive result. "The point at which brain effects show up will depend on the sensitivity of the study and the rigor of the epidemiology," he maintains.

But Cole argues that since "there is an impossibility of proving the absence of an effect—you can never, ever prove the negative"; the scale is unfairly tipped towards positive findings. He points to an EPA evaluation of 22 studies of health effects of lead; only five of these were considered to be any good, and of these only two—including Needleman's—showed any effects. And from this he concludes that "if there is an effect, it isn't all that severe."

Punctuating this conflict in basic approaches is continuous sniping over details of the scientific methods and conclusions of the various studies. Cole, for example, argues that the four-point difference in IQ that Needleman found is quite small; Needleman responds that "a lot of people who make that point should really know better" since a four-point difference in the mean can translate to a large difference in the wings of the distribution. There may be many more children in the high-lead group who are, say, below 75 in IQ. Cole counters that we don't know what the actual distribution is.

Needleman says that the El Paso study has "serious problems"; for example, "a lot of those people did not participate—there was litigation against the industry, and it is possible that the families of the kids most injured, who were bringing suit, would not participate in an industry-sponsored study." Cole claims that the excluded group did not differ in blood lead levels. Needleman argues that blood lead is an inadequate marker of past exposure. And so on.

Both ILZRO and Needleman are now working on prospective studies of lead's effect on children; the results of these studies may take away some of the ammunition of future sniping. Needleman plans to examine children from pregnancy on, measuring their total exposure to lead from air, food, water, and paint.

Unanswered questions

That work may also help to answer one of the genuine scientific questions that remains: What are the relative contributions of different sources of lead to typical human exposures. Getting the answer to that question could do much to halt the runaround among the regulatory agencies. (A recent report issued by the General Accounting Office confirms that the runaround continues. GAO found that the Department of Housing and Urban Development, which is charged with eliminating lead paint from federally assisted housing and which maintains that lead from sources other than paint is more important, is "not fully complying with its own regulations and procedures directed at eliminating the hazards of lead-based paint." Meanwhile, EPA continues to move slowly and cautiously on enforcing its ambient air standard for lead, even after it was recently upheld by the Supreme Court.)

Patterson is quick to insist that research on the relative contributions of different sources should not be relevant to regulatory strategies, however. He is convinced that the scientific evidence already in hand makes the case for eliminating exposures from all sources—and for halting mining of lead altogether. The political reality, though, is that technical fixes will be the short-term answer to lead pollution, and that until the buck-passing among the agencies stops, even these fixes will not be enforced.

Patterson points to a second unresolved scientific issue, one that is a sobering reminder and a capsule summary of the extent of lead contamination of the modern environment. "It is highly probable that many biochemical processes within the cells of humans and animals, universally subjected to lead pollution on a widespread scale, are highly perturbed and unnatural. It is a matter of great scientific interest to discover how natural biochemical processes operate under lead-free conditions. This means that such studies should be carried out in the future in lead-free sanctuaries." In our lead-contaminated world, Patterson is saying, there are no unperturbed controls. —Stephen Budiansky

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