

REVIEW

Clair Patterson and Robert Kehoe's Paradigm of "Show Me the Data" on Environmental Lead Poisoning

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In 1925, Robert A. Kehoe enunciated a paradigm predicated upon categorical distinction between expectations and conjecture ("show me the data" mentality) from hard scientific facts on exposure outcomes. It led to a precedent-setting system of voluntary self-regulation by lead industry as a model for environmental control and implicitly signaled the level of industrial responsibility for lead pollution. It combined a cascading uncertainty rule (there is always uncertainty to be found in a world of imperfect information) with a highly skewed cost-benefit concept (immediate benefits of tetraethyl lead additives must be weighed against possible future health hazards). Many studies were funded by the lead industry to develop a theoretical framework for the paradigm which served as a strong defensive strategy against lead critics. It resulted in an unfettered growth in automotive lead pollution to over 270,000 tons per year in the United States and 350,000 tons per year worldwide during the early 1970s. Clair Patterson is credited with being the first person to mount an effective challenge against the Kehoe paradigm, and with his success came an upsurge of activity and attention to the risks of environmental lead pollution on public health. © 1998 Academic Press

INTRODUCTION

On May 20, 1925, Hugh S. Cumming, then Surgeon General of the United States Public Health Service, convened a meeting of a diverse group of experts and concerned parties to consider the possible health hazards from the manufacture, distribution, and use of tetraethyl lead (TEL) as an additive in gasoline. The anti-knock properties of TEL were discovered in 1921, and

well before the gasoline containing this compound came on the market early in 1923, the risks from such widespread distribution of lead compounds had generated some concern among people in the labor movement and the public health community. The fears were intensified by later reports of fatal poisonings and other adverse health effects in the manufacture and mixing of concentrated TEL at plants in Deepwater, NJ, Dayton, OH, and Bayway, NJ. In a masterful public relations exercise, the makers of TEL stopped the distribution of TEL on May 5, 1925, and the sale of leaded gasoline was thereby generally discontinued. The Surgeon General's conference was then engineered to give scientific credence to the continued use of leaded gasoline.

In resorting to such a national conference, the Surgeon General was following the precedent of President Herbert Hoover, who had convened a conference on unemployment with a similar mix of interested parties while he was commerce secretary. By bringing together a representative assembly of business, labor, and public health leaders to examine all aspects of the controversial problem to come up with voluntary guidelines, the conference organizers had hoped to obviate the need for further government regulation. More importantly, Cumming wanted to use the conference as a means of bringing scientific (expert) methods to bear on the problem at hand. In his opening remarks, the surgeon general assured the participants that "It seems unnecessary to inform you that this is in no sense a legal hearing; in fact, there are no Federal laws which authorize the Public Health Service to take jurisdiction regarding interstate shipment of substances such as tetraethyl lead, even should it be determined that they are injurious to public health" (U.S. PHS, 1925,

p. 3). The first lead critic to speak at the conference (Yandell Henderson of Yale University) wasted no time in calling for precisely such a legislation to ensure that “such a situation as has arisen regarding leaded gasoline should not arise again” (U.S. PHS, 1925, p. 61).

The conference opened with two entrenched viewpoints; as Yandell Henderson, an ardent lead critic curtly noted, “The men engaged in industry, chemists and engineers take it as a matter of course that a little thing like industrial poisoning should not be allowed to stand in the way of a great industrial advance. On the other hand, the sanitary experts take it as a matter of course that the first consideration is the health of the people” (U.S. PHS, 1925, p. 62). In his opening remarks, Robert Kehoe (then a consultant to Ethyl Corp.) quickly preempted a key element in sanitary experts’ concerns by flatly declaring that “it seems perfectly plain at the onset that there was only one manner in which to deal with the problem, and that was not the treating of men who were sick, but the prevention of sickness among them” (U.S. PHS, 1925, p. 15). After discussing the initial success of safety measures that had been implemented in the TEL manufacturing plants, he declared that “there is every reason to think that by further close observation, by the closest attention to details of discipline and careful warning of these men, that the hazard at this point may be reduced to a point of complete disappearance.” It was imperative for Kehoe and his industrial clients to insulate the occupational lead hazard (which could be remedied by safe industrial practices) from environmental lead hazard (a new problem which could conceivably result in the restriction or even ban on the sale of leaded gasoline). Everybody in the room agreed that the horrible deaths that had occurred in the TEL manufacturing plants had to be stopped.

When Ethyl Corp., which owned the patents on use of TEL in gasoline, provided the assurance that it would solve the occupational hazard voluntarily, the conference was faced with the question of how to deal with the unprecedented problem of environmental lead pollution and its threat to human health. Calling TEL a “gift of God” and invoking technological progress as a necessary adjunct to the American industrial civilization (by Frank Howard of Ethyl Corp.) was having little persuasion over the moral charge made, among others, by A. L. Berres of the American Federation of Labor that “we are more concerned about taking and keeping the knock out of human being than we are in taking the knock out of motors We are against any progress

and efficiency that carries with it serious injury to humanity” (U.S. PHS, 1925, p. 96). As the public health experts turned the agenda to environmental issues, with the fate of Ethyl Corp. and TEL hanging in the balance (the most likely control option was a permanent ban on TEL), Robert Kehoe rose to enunciate a paradigm which led not only to the resolution of the controversy but to forestalling future controls on environmental lead hazards for nearly four decades (Loeb, 1994, 1997).

Before discussing his paradigm, the question needs to be asked: Who was Robert Arthur Kehoe? This giant among occupational physicians in the United States was born on November 18, 1893, in Georgetown, OH and died in Cincinnati on November 24, 1992, six days after his 99th birthday. He obtained his medical degree in 1920 from the University of Cincinnati and shortly thereafter was made an instructor in the Department of Physiology of the College of Medicine at the university. He was hired in May 1924 by Charles Kettering on behalf of General Motors to investigate the hazards at the TEL manufacturing plants. He rose professionally to become simultaneously the Director of the Kettering Laboratory, Professor of Industrial Medicine, Medical Director of Ethyl Corp., and key consultant to the lead industry. He gained scientific prominence in the mid-1920s and became the most vocal and outspoken American scientist on lead poisoning. He was very influential in the development of industrial hygiene and public health in the United States, and his accolades included being made Fellow of the American Medical Association (Vice Chairman, Council on Industrial Health); Member of the Governing Council, American Public Health Association; President of the American Academy of Occupational Medicine; Director of the Industrial Medical Association; Director and then President of the American Industrial Hygiene Association; Vice President of the Ohio Academy of Sciences; Vice President of Sigma Xi; and a recipient of many prestigious awards. Robert Kehoe and the lead industry were very closely entwined in more ways than just the theory and practice of occupational health protection—the lead industry built and equipped a laboratory for him, paid his salary (minus the \$1.00 per year he received from the University of Cincinnati), and financed most of his research. The return for the symbiosis included an unprecedented control on research and knowledge about occupational and environmental lead hazards and the stifling of environmental pollution control programs in the United States for many decades (Graebner, 1985). Robert Kehoe was not a modest man when discussing his influence and

industrial funding in shaping the research on lead poisoning done during his time: “at present, this [Kettering] Laboratory is the only source of new information on this subject [occupational and public health standards for lead], and its conclusions have a wide influence in this country and abroad in shaping the point of view and the activities, with respect to this question, of those who are responsible for industrial and public hygiene” (Kehoe, p. 4).

THE ROBERT KEHOE PARADIGM

After listening to the various pronouncements by Yandell Henderson (Yale), David Edsall (Harvard), Haven Emerson (Columbia), Alice Hamilton (Harvard), and others on the potential hazards of increased automotive lead emissions as well as the various calls for restrictive regulations, Kehoe responded with the following unusual but highly enticing argument:

I am convinced from the association I have had with the company that has had charge of the distribution of this commodity and their attitude is one with complete regard to facts. They have expressed themselves repeatedly not so much as being interested in opinions as being interested in facts, and if it can be shown—if it is shown as a result of this discussion—that an actual hazard exists in the handling of ethyl gasoline, that an actual hazard exists from exhaust gases from motors, that an actual danger to the public is had as a result of the treatment of the gasoline with lead, the distribution of gasoline with lead in it will be discontinued from that moment. Of that there is no question When a material is found to be of this importance for the conservation of fuel and for increasing the efficiency of the automobile it is not a thing which may be thrown into the discard on the basis of opinion. It is a thing which should be treated solely on the basis of facts. That has been our attitude from the beginning and that will continue to be our attitude (U.S. PHS, 1925, p. 70).

At the conference, the public health experts had little scientific evidence to justify their claims about potential risks to the public. Most of the data presented at the conference came from the industries themselves and from industry-sponsored studies by the Bureau of Mines of the U.S. Department of the Interior. In assessing the “facts” as they were presented at the conference, Frank Howard, a spokesman for Ethyl Corp., General Motors Corp., and Standard Oil Co. (NJ) gloated that:

I do not think we are justified in trying to reach a final conclusion in this matter on fears at all; nor are we justified in saying that we will cease this development because of fears we entertain. This development must be stopped, if it is to be stopped at all, by proofs of the fact Now on that point, I think this conference has had a wonderful effect. We

have had presentations of facts on both sides. But I must say—perhaps I am a little biased—that most of the facts presented have been in favor of the use of tetraethyl lead product (U.S. PHS, 1925, pp. 106–107).

Me. de M. Touart (then medical director of Reconstruction Hospital, New York City) offered a weak and ineffectual counterargument: “It has been said today that industry was willing or is willing, if it is shown *conclusively* [emphasis is mine] that the use of leaded gasoline is a hazard to the general population, to cease the distribution of the same. It seems to me that perhaps the attitude should be taken that this ethyl gasoline is under suspicion and therefore should be withheld from public consumption until it is conclusively shown that it is not poisonous” (U.S. PHS, 1925, p. 79). With large investments by General Motors, Standard Oil Company (NJ), and Ethyl Corp. at stake and considering the social and economic climate of the 1920s, which was rooted in a firm belief in industrial progress geared to the automobile, the outcome of the discussions was pre-ordained.

The table was turned against the public health experts and the Kehoe paradigm was affirmed. The public health experts, however, managed to salvage something out of the meeting and the following resolution was adopted at the end of the conference.

It is the sense of this conference that the Surgeon General of the United States Public Health Service appoint a committee of seven recognized authorities in clinical medicine, physiology, and industrial hygiene, to present to him, if possible, by January 1 next, a statement as to the health hazard involved in the retail distribution and general use of tetraethyl lead gasoline motor fluid; . . . that the investigation shall be paid for exclusively out of public funds; and that the results of this investigation shall be reported back to the public conference called for the purpose by the United States Public Health Service, at which labor shall be represented (U.S. PHS, 1925, p. 116).

The report of the blue ribbon committee was released at another public conference on January 17, 1926. It concluded that in their opinion, “there are at present no good grounds for prohibiting the use of ethyl gasoline of the composition specified as a motor fuel, *provided that its distribution and use are controlled by proper regulations*” (U.S. PHS, 1926, p. 110). It should be noted that the recommendation focused on the hazards from the distribution and use (i.e., environmental risks) more than on occupational hazards which could be controlled using suggestions that were provided by the committee. In fact, the title of the committee’s report was *The Use of Tetraethyl Lead Gasoline and Its Relation to Public Health* (U.S. PHS Bulletin No 163, 1926); the

manufacture of TEL and associated industrial hazards were not the issue. In reaching its conclusion, the committee referred to a number of poignant concerns about potential environmental hazards of leaded gasoline. The report concluded:

It remains possible that, if the use of leaded gasoline becomes widespread, conditions may arise very different from those studied by us which would render its use more of a hazard than would appear to be the case from this investigation. Longer experience may show that even such slight storage of lead as was observed in these studies may lead eventually in susceptible individuals to recognizable lead poisoning or to chronic degenerative diseases of a less obvious character. In view of such possibilities the committee feels that the investigation begun under their direction must not be allowed to lapse. ... It should be possible to follow closely the outcome of more extended use of this fuel and to determine whether or not it may constitute a menace to the health of the general public after prolonged use (U.S. PHS, 1926, p. 110).

After the committee's report was released, Ethyl Corp. voluntarily adopted the recommended safety measures to reduce the occupational hazards in a preemptive effort to forestall any legislative measures at the state and federal levels. Nothing, however, was done about the key piece of the committee's report—protection of public health. Perhaps the committee may be faulted for providing detailed guidelines on how to reduce industrial lead hazards but only recommending further study of environmental health risks. The Public Health Service refused to fund any further study but instead took Dr. Kehoe's advice that "as it appeared from their investigation that there was no evidence of immediate danger to the public health it was thought that these necessarily extensive studies should not be repeated at present at public expense, but that they should be continued at the expense of the industry most concerned" (Cited in Rosner and Markowitz, 1985, p. 351).

As the first official action on hazards of environmental lead pollution, the Surgeon General's subsequent action (see below), dictated by the Kehoe paradigm, set a precedent for future decisions on such health and safety issues. It codified voluntary self-regulation rather than legislation as the model for environmental control, thereby defining the limits to industrial responsibilities for lead pollution and poisoning for many decades. In discussing the implications of voluntary self-regulation on lead poisoning, Loeb (1997, p. 11) notes that "because this kept the relationship of industry to government from being adversarial it helped to build a harmonious political order in which companies felt that what they did was in the public interest. It also signaled

the federal role in determining health effects, and rather than raising public consciousness of air pollution hazards it assured the public that no harm would arise. Thus, public concern over the toxicity of emissions was put aside."

To lead industry representatives at the conference, the principle of "show me the data" had worked. To make it more effective as a tool against future attacks, it became imperative that the industry continue to be at the forefront of research and data collection that could be used to embellish the industry's particular viewpoints. An unparalleled hegemony was soon to be established on medical research and scientific knowledge pertaining to lead poisoning in the United States, with Robert Kehoe as the kingpin.

KEHOE'S PARADIGM ENGENDERED AN UNFETTERED GROWTH OF LEADED GASOLINE

Alan P. Loeb (1994, 1997) has written two very spirited articles on the 'Kehoe Rule' and provided detailed discussions of its ramifications in subsequent study of lead poisoning in the United States. The following section draws heavily on Loeb's careful and painstaking research. This report, however, prefers "paradigm" to "rule" for describing the same phenomenon since what Kehoe enunciated was more of a proposition than a careful definition on how environmental health issues should be decided.

The paradigm characterized any risk assessment of environmental lead poisoning as fraught with uncertainty: "if it can be shown that an actual hazard exists ... the distribution of gasoline with lead in it will be discontinued at that moment." Kehoe knew such an assurance carried no weight. Implicitly, he was advocating the continued use of toxic TEL until the consequences could be determined later. With time, the effects of applying the paradigm were bound to become manifest. When they did, there could be one of two possible outcomes: (a) if the health risk from automotive lead pollution turned out to be negligible, then the Kehoe paradigm had led to a wise decision in assuring the public that there was no hazard to be protected from; (b) if on the other hand the use of leaded gasoline became a health hazard, it would take a long time to prove. In a world of imperfect knowledge, especially if the industry controlled most of the information, it would always be easy to find uncertainty in any study. In describing the paradigm as a contingency rule, Loeb (1994, p. 81) notes that "both possible outcomes accommodated Ethyl. The general public was dealt all

the risk and Ethyl and its owners were insulated from responsibility. To the extent that there was a health consequence, the Kehoe rule placed the burden upon the public.”

It is easy to see why “show me the data” became a powerful defensive strategy against critics of leaded gasoline and other leaded products. In a world of imperfect information, it would be impossible to provide a definitive cause–effect relationship to justify action on the part of the lead industry or the legislators. Its continued application calling for substantial expenditure on lead poisoning research was designed primarily to generate uncertainty in any uncompromising studies and thus provided the framework for much of the activities of lead advocates in the public health arena for nearly half a century. Some people may claim that the paradigm and the way it has been applied are not exactly new. The tobacco industry, for instance, has also perfected a similar paradigm, which was used to weather all liability claims against it until recently. There is, however, a big difference. Whereas smoking is a voluntary habit, few people or organisms chose to be exposed to toxic fumes from automobile exhausts. Furthermore, a cigarette represents a risk primarily to the smoker, whereas automobile emissions threaten the health of entire communities and ecosystems. Variants of the Kehoe paradigm have also been adopted by the mercury, asbestos, and other industries to defend their products.

The paradigm introduced a highly skewed cost–benefit concept in dealing with environmental lead issues: “when a material is found to be of this importance for the conservation of fuel and for increasing the efficiency of the automobile it is not a thing which may be thrown into the discard on the basis of opinion. It is a thing which should be treated solely on the basis of facts.” The economic benefits of TEL (highly touted) must be weighed against the potential health cost (indirect, remote in time consequence, and unproven). The issue of benefits and risks in light of uncertainty in knowledge was to permeate subsequent future debates on environmental lead hazards (Loeb, 1994). The following excerpt provides an excellent flavor of the Kehoe paradigm in such debates:

For several years, controversy has surrounded the use of lead alkyl anti-knock additives in gasoline. Dozens of public hearings on the topic have been held across the country. A virtual army of scientists and technicians have studied the issue. Regulations have been proposed and debated. Yet, despite this tremendous amount of activity and research, the issues remain much what they were in the beginning. The search for a solid, factual, scientific basis for claims

against lead has produced nothing of substance ... Scientific evidence does not support the premise that lead in gasoline poses a health hazard to the public, either now or in the foreseeable future (Cole, 1975, p. 1).

In essence, the Kehoe paradigm required the public health community to provide hard data on allegations before remedies would be found necessary. Since the paradigm was not legally enforceable, trying to demonstrate violations was like shooting at a moving target. In reality, the Kehoe principle provided the public no greater protection from exposure to lead than what was available under the common law rules of nuisance (Loeb, 1994). Careful application of the paradigm invariably put the burden of proof on the critics of lead according to an industry-defined scale. That burden was very difficult to meet in the face of uncertainties raised by Ethyl Corp. and the lead industry.

The reverse side of “show me the data” is the impossibility of proving a negative, a safe fallback position for the lead industry also. The report of the seven-member blue ribbon committee noted that in their opinion “there are at present no good grounds for prohibiting the use of ethyl gasoline.” It did not state or even imply that the use of TEL was safe. Nevertheless, the outcome of the conference was widely reported as giving leaded gasoline a clean bill of health. That gave the public a sense of assurance (misplaced trust) which the lead industry carefully safeguarded by minimizing public attention to the problems through information engineering and by taking stringent steps to deny knowledge about the hazards to the public. If the public assurance became breached, the lead advocates would use the Kehoe paradigm to argue that they did not know and that no one yet knows. The Kehoe paradigm thus was a bifocal proposition with either angle favoring an industry that opposes regulation and is committed to defending its position using the weight of scientific and medical evidence.

The impacts of the Kehoe paradigm were pervasive. Its manifestations and applications in silencing lead critics have been well documented in a number of reports (see, for example, Wormser, 1947; Graebner, 1988; Sellers, 1991; Lin-Fu, 1992; Loeb, 1994, 1997; Needleman, 1998). It succeeded admirably in providing an atmosphere for unfettered growth in the production of leaded gasoline. With resumption in the sale of leaded gasoline in June 1926, consumption rose steadily and by the early 1950s, the production of TEL used over 100,000 tons of lead per year and ranked among the top 10 industrial chemical enterprises in the United States (Nickerson, 1954). By the early 1970s when leaded gasoline was the

“tiger in the tank of almost every car.” the sale of leaded gasoline exceeded 270,000 tons in the United States and 350,000 tons worldwide. It has been estimated that between 1926 and 1985, over 6 million tons of lead was burned as gasoline additives in the United States alone (Nriagu, 1990). As the unprecedented lead pollution grew, the lead advocates became more strident in the use of Kehoe paradigm to defend their action:

We recognize the admonishments of those who oppose the continued use of lead in gasoline because of speculative though unrecognized ill effects. They state that the use of lead ... must be proved safe by industry before continued use should be allowed. The problem with this philosophy is that it does not define “proof.” One can never be absolutely certain that any substance, whether present naturally or artificially in the environment is absolutely safe, i.e., producing no ill effects whether recognized or unrecognized. Using today’s measurement techniques, we conclude that the use of lead in gasoline is safe. It is admitted that where we lack adequate measurement techniques, we are ignorant of the effects of lead ... This ignorance is a reason for continued research but not a reason for stringent restrictions, for if the latter philosophy were widely adopted, our society would suffer immeasurably (Editorial Comments by Cole, 1975, p. 5).

The architect of the paradigm (Robert Kehoe) was then able to boast that “The bulk of the investigative work which bears on lead in the general population of man has been carried out, under the financial sponsorship of the manufacturers and distributors of lead containing anti-knock compounds in the United States, in the Kettering Laboratory, in the Department of Preventive Medicine and Industrial Health of the College of Medicine of the University of Cincinnati” (Muskie Hearings, 1966, p. 207).

CLAIR PATTERSON STRIKES AT THE KEHOE PARADIGM

Pundits will argue for years about the influence of Clair Patterson in the contemporary study of environmental lead pollution and its effects on human health. The history of this issue is still evolving as the perception of TEL changes from being a “gift of God” to being a curse of the gods (Nriagu, 1990). When the mist of history clears, his legacy will include the fact that he was the first person to unmask the lack of scientific objectivity in the Kehoe paradigm. He was able to mount an effective challenge against entrenched beliefs using a combination of personal conviction, a sense of moral outrage, and scientific facts that could not be stifled by the Kehoe paradigm.

Clair Patterson was the first person to see through the ramifications of the Kehoe paradigm and to chal-

lenge them publicly. Only selected examples will be used here to illustrate the forceful nature of his effort. In his testimony before the hearings by then Senator Edmund Muskie on air and water pollution, Patterson charged that the best interest of public health had not been served by having public health agencies work jointly with representatives of lead alkyl industries in evaluating the hazards of automotive lead to public health. He took particular umbrage to the cloaking of the paradigm in a mantle of science:

It is clear, from the history of development of the lead pollution problem in the United States that responsible and regulatory persons and organizations concerned in this matter have failed to distinguish between scientific activity and the utilization of observations for a material purpose. [such utilization] is not science ... it is the defense and promotion of industrial activity. This utilization is not done objectively. It is done subjectively. ... It is not just a mistake for public health agencies to cooperate and collaborate with industries in investigating and deciding whether public health is endangered—it is a direct abrogation and violation of the duties and responsibilities of those public health organizations. In the past, these bodies have acted as though their own activities and those of lead industries in health matters were science, and they could be considered objectively in that sense (Muskie Hearings, 1966, p. 315).

Scientific objectivity was the underlying theme of the Surgeon General’s conference and the reason behind the public acceptance of the findings. It was a key element of the Kehoe paradigm. As Patterson indignantly observed above, voluntary self-regulation according to the paradigm served the interest of the industry and did not protect human health.

Patterson did not just stop with exposing the Kehoe paradigm as being antithetical to public health, he also challenged most of the theoretical framework developed by Kehoe and the industrial establishment in support of their position. Kehoe had maintained that lead was a natural constituent of the environment and that a certain level of lead absorption was “normal.” From mass balance studies using volunteers, Kehoe concluded that in most instances, exposure to lead would result in an equilibrium situation in which the quantity of lead taken in is equivalent to the amount eliminated. Patterson (1965) drew attention to the fallacy of assuming that observed (“typical”) lead in foods and bodies of Americans are natural and therefore safe and harmless. He used a geochemical argument to estimate that the average (typical) body burden and concentrations of lead in the blood of Americans in the 1960s were at least 100 times above the background values. By “showing them the data” obtained using

his unassailable techniques, he was able to turn the tables on proponents of the Kehoe paradigm.

An important cornerstone of Kehoe's theoretical edifice was the threshold concept of lead exposure and lead toxicity. Kehoe introduced the methodological innovation of using the safe workplace concentration (level of exposure) as a hazard management tool in the lead industry. Within the framework of the paradigm, such quantitative estimates of acceptable exposure levels were presented as the wisdom of scientific specialists and served to discourage further inquiry by the untrained or less specialized individuals. They were used as tools to protect scientific authority as much as the workers and to isolate the work of the experts from social controversy. From chamber studies, Kehoe was able to estimate the safe exposure concentration for airborne lead to be about $100 \mu\text{g}/\text{m}^3$ (see Heimann, 1965, p. 146), which led him to the conclusion that "from the consideration of the observed facts and the physiological principles developed, it would appear that there is no reasonable basis for anxiety concerning potential threat that is offered to the public from lead in the ambient atmosphere in the United States" (Muskie Hearings, 1966, p. 225). Patterson, however, addressed the issue of safe exposure concentration from a geochemical perspective. He estimated the background (preindustrial) atmospheric lead concentration to be $0.0005 \mu\text{g}/\text{m}^3$. By comparing this value with the then ambient concentration of $>1.0 \mu\text{g}/\text{m}^3$ in urban areas, he arrived at the conclusion that industrial lead was responsible for the 2000-fold rise in ambient lead level. When asked the significance of his observation, he deadpanned: "you can use the data to justify your purposes. If your purpose is to sell lead alkyls, then you look at these data one way. If your purpose is to guard public health, you will look at this data in another way, and you will reach different conclusions" (Muskie Hearings, 1966). There was no doubt in his mind, however, that the data pointed to the fact that the average resident of the United States was being subjected to severe chronic lead insult (Patterson, 1965).

"Toxic limit" was another important tenet of the physiological basis for the Kehoe paradigm. Using lead content of blood as a bioindicator of exposure, Kehoe had concluded that "in the case of infants and very young children, the onset of lead poisoning has not been found to occur in association with levels of lead concentration in the blood under 0.08 mg per 100 g of whole blood" (Muskie Hearings, 1966, p. 222). Under the rubric of the paradigm, lead poisoning was rigidly defined in clinical terms (Kehoe,

1963), thereby reenforcing the uncertainty principle since the symptoms of lead poisoning are often ill-defined (see Wormser, 1947). Patterson (1965), by contrast, argued that classical lead poisoning represents but one extreme of a continuum of reaction of an organism or human body to various levels of lead exposure. He surmised that below the then accepted threshold concentration there were some effects which clinically might be difficult or impossible to detect or ascribe to their real cause.

Through his writings, lectures, testimonies, and appearances before congressional hearings, Patterson was able to tear down the "show me the data" mentality which clouded much of the Kehoe-era work on environmental lead poisoning. Patterson's successful challenge of the Kehoe paradigm marked the upsurge of activity and attention in the United States to the potential harm to the general public from contamination of the air with lead from industries and the automobile. Kehoe's (1966) continuing assurance that lead poisoning "has been brought to such point of understanding, in relation to public health, as to remove it from the realm of urgency and to consign it into that group of hygienic problems on which a watchful and effective surveillance should be kept" (Muskie Hearings, 1966, p. 204) increasingly fell on deaf ears.

Herbert Stokinger, former Chief of Toxicology of the U.S. Public Health Service, was a close friend of Robert Kehoe and the lead industry. In a letter he sent to the Editor of Archives of Environmental Health, he lamented the publication of Patterson's (1965) paper in the journal: "On the other hand, this article has furnished the requisite fire to start off groups interested in public health on a large and necessary program of investigation of the matter" (Muskie Hearings, 1966, p. 318). History shows that Stokinger's worst nightmare soon came to pass.

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