LEAD POLLUTION

— Dr. Clair Patterson
CalTech, Pasadena

Lead is only a trace element in the earth, averaging about 12 parts per million in its surface rocks. During the course of evolution most plants growing in soil came to exclude rare heavy metals in favor of the more abundant lighter metals. Similar exclusion-enhancement mechanisms evolved in herbivores and carnivores. Complex organisms like men, existing near the ends of food chains, are therefore relatively pure in nutritious abundant light metals compared to the earth's rocks, and are relatively free of toxic rare heavy metals because of the cumulative operation of exclusion-enhancement mechan[illegible] ong successive stages in food chains. The natural levels of [illegible] iffer [illegible] biosphere are not yet known, but observed fract[illegible] wee [illegible] can be used as analogues to estimat[illegible] um [illegible] bundant than lead in soil, it p[illegible] nes [illegible] uncontaminated terrestrial plant[illegible] 0 ti[illegible] bundan[illegible] uncontaminated [illegible] als. [illegible] me [illegible] ingestio[illegible] amounts larger than those [illegible] to [illegible] he[illegible] mful to man.

Only a minor fraction o[illegible] ead [illegible] food enters the intes[illegible] al blood, most of it being excreted. The live[illegible] tha[illegible] wn lead from portal [illegible] rejects it with bile before it can en[illegible] the main systemic blood st[illegible] so that about 95 % of the lead taken by mouth is finally excreted in feces. [illegible] ue for lead breathed into [illegible] lungs. About 40 % of such lead enters the [illegible] stemic blood, and atmospheric lea[illegible] erefore a much more seri[illegible] ontaminant. Mos[illegible] ead absorbed into body fluid [illegible] in urine after a [illegible] y short time. [illegible] ver, a small fraction of the [illegible] ead is retained for long periods in the body, mainly in the bones, where it a[illegible] s a sluggish reservoir in contact with the blood, slowly accumulating or draining according to changes in the rates of lead ingestion. In natural circumstances body concentrations of lead probably at first increase rapidly with age in the child and then increase more slowly in the adult. As an enzyme inhibitor, lead impairs cell metabolism in the body and thereby disrupts the natural functions of organs made up of those cells. In some instances of excess lead ingestion, as in cases of gross dysfunction of the brain, or muscles, or kidneys, the cumulative impairment of the metabolisms of multitudes of cells in the body is recognized as classical lead poisoning. In other instances of excessive lead ingestion, when organ dysfunctions are less severe and symptoms less overt, the widespread impairment of cell metabolism is termed chronic lead insult.

Man cannot eat food containing even one-tenth the average concentration of lead in soil, that is, about 1 part per million, for very long without becoming ill with classical lead poisoning. Man's food in industrialized societies is contaminated with lead, and it contains about 0.2 parts per million of lead. It is likely that the uncontaminated food of man's ancestors contained much less lead, perhaps only 0.01 parts per million. In prehistoric times natural water and air contributed amounts of lead to the body which were insignificant compared to that in food. In natural circumstances a man probably consumed each day about 20 micrograms of lead in food, and on this basis he excreted about 19 micrograms in his feces, absorbed about 1 microgram into his blood, stored a small fraction of that in his body and excreted a little less than a microgram in his urine. At late maturity he probably contained a total burden of about 2 milligrams of natural lead in his body.

Historical Note

Man's troubles with industrial lead began about 2500 B.C., near the end of the Chalcolithic era in southwest Asia. By that time men were mining and smelting metal ores and they were well acquainted with the remarkable utility of bronze and the value of gold. In their attempts to smelt useful bronzes from different, abundant ores, they had finally discovered that small amounts of silver could be parted (cupelled) from lead metal which had been first smelted from lead ores. Previously, native silver had been much rarer than gold, and perhaps more esteemed. Traces of silver occur commonly in galena, an abundant lead sulfide ore, and silver production from lead ores boomed after 2500 B.C. The mines were worked by slaves whose lives were brief and painful. About four hundred tons of lead in oxide form were produced for every ton of silver obtained by cupellation. Lead oxide was easily converted to metal again by reduction with charcoal. With the advent of coinage in 650 B.C., silver became a keystone in the founding and operation of successive civilizations and lead production rose sharply. The glory of Greece and the grandeur of Rome were founded upon the lead mines of Attica and Spain.

During the two millenia beginning with the cupellation of silver from lead ores and ending with the commencement of coinage, men found a multitude of uses for the huge piles of lead that began to accumulate. By Classic Greek times water was being collected from lead-covered roofs, and transported through lead metal gutters to lead-lined cisterns. Stone building blocks were being held together with iron clamps imbedded in lead metal that had been poured into holes drilled in the stone. Ships were being sheathed with lead metal to repel wood-worms. Salves, ointments, cosmetics, and paints were being made of lead compounds. Grape sugars boiled down in lead pots, were being added to wines to keep them from souring (1). Lead-tin alloys were being widely used to line the insides of bronze utensils to keep copper out of foods and liquids.

The industrial use of lead in the world reached a monumental plateau during the 1st and 2nd centuries of the Christian era. In Italy, the annual industrial use at the time amounted to nearly 0.004 ton of lead/person/year, which almost equaled the 0.006 ton of lead/person/year industrially used in the United States two thousand years later. The Romans exhausted all the lead mines within their empire down to several hundred meters below the water table by about A.D. 300, and world lead production declined precipitously with the fall of Rome, and then remained at a low ebb during the following six centuries. Production again began to climb slowly in Europe after the 9th century A.D., when most lead mining activities shifted from holdings in the declining Byzantine Empire to virgin deposits operated by free entrepreneurs in central Europe. During the late Renaissance, world lead production finally reached the former mighty levels achieved by the Romans, after entire Indian nations became enslaved in the lead mines of Peru and Mexico. Beginning with the Industrial Revolution, world lead production climbed exponentially from 100,000 tons/yr in 1750 to 3,500,000 tons/yr in 1966 (2).

Today there is evidence of intense, widespread pollution of the earth's surface by industrial lead. Studies of the accumulation of lead in oceanic sediments show that 11,000 tons of dissolved lead/yr were added during prehistoric times to all the oceans of the northern hemisphere by rivers draining all land areas there (3). This flow of dissolved lead through the earth's natural sedimentary geochemical cycle is now quite small compared to the massive 3,500,000 tons/yr flow of industrial lead through man's urban environment, and there is evidence that geochemical balances in some portions of the earth have been modified as a consequence. Measurements of lead in rivers, atmosphere and oceans in the northern hemisphere suggest that the present annual input to the oceans may be about 430,000 tons of dissolved lead/yr, the forty-fold increase coming from industrial pollution and agricultural stimulation of soluble denudation (4).

The young, upper layers of the oceans appear to contain about five times more lead than is natural, compared to underlying ancient waters, which are not yet much affected (5). The concentrations of industrial lead in the atmosphere at remote locations in the Pacific and the Arctic are hundreds of times above natural levels established by silicate dusts and other natural airborne constituents (6). In urban areas the excess of industrial lead in the atmosphere is about 10,000 times above natural levels (7). Mosses collected in Scandinavia over the last century and analyzed recently, show a ten-fold increase in lead content during this period near cities with the increases becoming smaller at locations remote from roads and urban areas (8). In cities of North America concentrations of lead in upper layers of soil have risen ten-fold. Annual layers of snow in Greenland near the North Pole show progressive increases of industrial lead with time above natural levels during past centuries, present concentrations being excessive by a factor of about 500. At the beginning of the Industrial Revolution, lead concentrations in Greenland snow were already 25 times above natural levels, and they continued to rise steadily during the next two centuries to 150 times above natural. Nearly all of this excess lead probably originated from lead smelteries. At about 1940 lead concentrations in snow rose abruptly, probably because of massive new additions of lead aerosols from automobile exhausts, and increased by a factor of three in only two decades (9).

Obvious evidences of lead pollution have caused conflicts to arise between private industrial interests and public health interests. Chemical industries manufacturing lead alkyls and petroleum industries adding them to automotive fuels are the most powerful defenders of the use of lead and at the same time contribute the largest identifiable share of lead pollution. In 1966 these industries used 310,000 tons of the world's annual production of 3,500,000 tons of lead to manufacture a product that was completely burned in ambient air. Lead exhausts from this product then entered the bodies of people directly via the lungs from air or indirectly via the intestines by fallout on food.

Petroleum industries came to depend more and more upon lead alkyls during the last 45 years because they decided in the beginning to meet demands for better fuels by purchasing a costly chemical additive out of current funds on short-term bases, rather than risk large investments on refining developments that had to be amortized over long periods in uncertain future markets. The huge sums subsequently expended on lead alkyls over past decades characterize the additional investment the petroleum industry would have needed to make on refining equipment, had they chosen not to use lead additives. The risk of amortizing the cost of a complete switch from using lead additives to actually refining better fuels is very much greater now than it was in the past. In addition, the petroleum industries have become accustomed to meeting differences between market demands and their rather inflexible refinery outputs and to correcting refining errors by adjusting the amounts of lead additives used, and they fear the risk of being required to depend upon mobility and accuracy in refinery production, because no precedent exists for this more complex plant operation, and they have no large-scale previous experience to draw upon.

The lead alkyl producing and consuming industries have successfully used two methods to exert pressure in favor of the continued use of lead alkyls: invoking the threat of economic penalty if lead alkyls are not used; and acquiring data concerning the public health hazards of lead pollution which favor their cause.

In testimony before public health agencies and legislative bodies, and by information disseminated in public literature, industry has refused to explain that lead additives are alternatives to complex refining methods and that the use of lead additives imposes additional costs on the automobile owner through plug fouling and engine corrosion. Instead, industry maintains without equivocation that lead alkyls are so essential that automotive traffic will grind to a halt without them. The petroleum industry alone posesses all the information needed to properly evaluate the economic feasibility of eliminating lead alkyls, but no legislative committee can pry it from them at present. Only naked threats by the public to take over the automotive fuel industry would shake that industry's resolve in this matter.

The lead alkyl industries have enjoyed spectacular success in manipulating public opinion on the health hazards of lead pollution. In 1924, Aub, a distinguished specialist in lead poisoning, and his colleagues published a definitive work on the subject, wherein they claimed that lead did not exist naturally in humans, but was present only in those persons contaminated by industrial exposure (10). It was difficult to detect lead in any but badly contaminated persons at the time because methods then in use were rather insensitive. This was a correct approximation, but it came at an unfortunate time because it proved to be a perfect foil for Kehoe, a young doctor at the University of Cincinnati Medical School, who had been hired by the Ethyl Corporation to unearth data which could be used to defend their manufacturing practices. Using newer and more sensitive methods Kehoe was able to demonstrate that lead was present not only in typical human food and feces, but in their blood and urine as well. Other investigators confirmed his findings. By thus disproving established experts, Kehoe gained, in time honored fashion, stature and respectful notice.

In the following decades Kehoe, financed by the Ethyl Corporation, developed three major principles that have since become enshrined in medical texts: (I) the equality of natural, uncontaminated lead states with typical, contaminated lead states (natural lead is ubiquitous in nature and man, existing in amounts comparable to those introduced by industrial pollution, and so variable in concentration from one place to another that it is impossible to distinguish between natural and industrial lead contributions); (II) the threshold for damage concept (persons are absolutely healthy and completely free of any form of lead disease for all levels of lead exposure and ingestion up to a certain, high, knife-sharp value of lead concentration in the body, beyond which, persons are suddenly stricken with classical lead poisoning - the emphatic terms in this statement originate with Kehoe); and (III) the equilibrium concept of the flow of lead through the body and its equality with harmlessness (except for unusual occupational exposures, typical, contaminated persons excrete in urine as much lead as they absorb in systemic blood, and since the body is thus able to "detoxify" any industrial pollution lead that enters its fluids in typical circumstances, such lead does no harm) (11).

There was a dearth of basic academic research on the biochemistry of lead in the period 1925-1965, and Kehoe's work filled that void. The views of the lead alkyl industries, cloaked in an aura of academic and scientific respectibility, therefore remained unchallenged for forty years and came to be regarded as the best medical information available on the hazards of lead pollution, instead of the defensive propaganda it actually was.

Influential public health organizations, such as the U. S. Public Health Service and some Departments of Public Health in a few populous U. S. states and cities, were indoctrinated in their earliest years with the view that lead poisoning was an occupational hazard, and during the first part of the 20th century they applied themselves with success to the alleviation of classical lead poisoning among industrial workers. This view, at odds with best public interest, had its origin in Europe during the 18th and 19th centuries. Correlations between occupation and disease were developed by medical practitioners during this period into powerful diagnostic aids. The obvious value of this practice placed the idea of occupational health hazards in a morally righteous setting, and this, in turn, acted in two unfortunate ways: it short-circuited any growth of an awareness of environmental poisons; and it established the divine right of hazardous manufacture.

Several centuries ago, people had been on the brink of recognizing lead as the first great environmental poison, but the opportunity vanished as more and more persons came to believe that lead poisoning was always associated with the improper handling of lead and that a lack of lead poisoning was always associated with its proper handling. The corollary of this belief upheld the divine right of hazardous manufacture: responsibilities concerning the health hazards of lead can be partitioned and separately assigned in each step from mine, to factory, to home. The absurdity of this belief appears when one considers (to take only one out of a multitude of examples) the fifty thousand children in the ghettos of big U. S. cities classically lead-poisoned at this moment from old paint, whose brains, kidneys, and livers are irreparably damaged (12) : where, back along the tortuous route to the lead ore deposits of Mexico, does blame for this crime rest?

The classic overt application to the lead pollution problem of the idea of occupational hazard and partitioning of responsibility is the action taken by the U. S. Public Health Service upon considering the public health hazards of lead alkyls in 1925, when it specified how the environmental poison lead tetraethyl should be manufactured without acute hazard to workers in the manufacturing plants, but made no recommendations limiting the amounts to be manufactured, and when in 1959 it increased the maximum allowable recommended concentrations of lead alkyls in gasoline, again without placing limits on the amounts to be manufactured (13, 14). The 1959 action is remarkable since it followed upon a decade of thorough public indoctrination on the subject of environmental poisons brought about by the testing of atomic weapons.

Public health organizations have engaged in another practice detrimental to public interests by working jointly with lead industries in evaluating public health hazards of lead pollution. In such dealings, public health officials profess to believe that independent of motives, true facts concerning the hazards of lead pollution can be ascertained by scientific methods, and these facts will then determine the issue, letting the chips fall where they may. An outstanding example of such hypocrisy is the study reported in 1965 by "The Working Group of Lead Contamination" of the health hazards of lead alkyls, and made jointly by the U. S. Public Health Service, the California State Department of Public Health, and various manufacturers and users of lead alkyls (15). This report, which absolves lead alkyls of any pollution effects and public health hazards, has been fondly quoted and referred to by the petroleum and lead alkyl chemical industries in their attempts to manipulate public opinion since 1965.

Research on the biochemistry of lead sank into doldrums in the 1920's. Most of the basic work carried out during the next several decades has been summarized and reviewed by Cantarow and Trumper (16). Interest in the field seems to have revived now that Kehoe's popular views have been disputed by geochemists studying the isotopic evolution of lead in the earth. Some isotopes of lead are formed from the radioactive decay of long-lived uranium and thorium, and certain geological occurrences of lead are useful for dating rocks and tracing their chemical history. In order to study common, ubiquitous minerals of geologic importance, investigators must isolate and measure the isotopic compositions of microgram amounts of lead, because the minerals contain no more than that. These minute amounts of lead are extremely succeptible to contamination, and elaborate precautions have been developed during the last several decades to exclude industrial lead contamination down to very low levels. It was this background of an acute awareness of the pervasiveness of industrial lead contamination combined with an experience in handling small quantities of lead that helped geochemists stumble on to the discovery that the oceans were being polluted with industrial lead. Investigators were interested in the oceans because they serve as giant mixing bowls for different leads derived from all lands. Pollution effects had not been previously recognized because ocean lead concentrations are small and difficult to measure.

As a geochemist involved in this work, I organized what was known about the occurrence and distribution of lead in natural and contaminated environments into a coherent study and published it in 1965 (17). To compare unknown natural lead environments with typical, polluted ones, I formalized some enhancement-exclusion relations among the alkaline earth group of metals in soil, plants, and animals, and then used the observed natural abundances of lead in soil and the above relations as analogues to extrapolate lead values in natural food and human bodies. This body burden value was checked by interpolation from the human body abundances of metals in group 4-b and row 6 of the periodic table. It was shown by material balance considerations that most of the lead in our food, water, air, and bodies probably originated from lead mines.

The average urban American ingests about 350 micrograms of lead each day in food and water and some 20 to 50 micrograms of lead in the air he breathes. He absorbs 30 to 40 micrograms of lead per day into his main bloodstream, about half coming from the air. He has an average body burden of 200 milligrams of lead, and an average blood lead concentration of 0.25 ppm.

I suggested that the health hazard of this typical, contaminated state could be evaluated from its position on a scale reaching from natural, uncontaminated states to classically lead-poisoned states. This might be done on the basis of blood lead concentrations, since they rise with increased lead exposure and ingestion. On the basis of estimated natural lead body burdens, it was assumed that natural blood lead concentrations should be less than 0.01 ppm. Classical lead poisoning is generally associated with blood lead concentrations of 0.8 ppm. Since the average American has 0.25 ppm of lead in his blood, I proposed that the average American was suffering severe chronic lead insult, probably with adverse effect.

Natural lead states were defined in the report and it was shown how Kehoe had attached a natural meaning to his term "normal", and then used this term to describe his analyzed subjects and their food, conveying the impression that they were natural and unpolluted when in fact they were typical and polluted with lead. It was shown how Kehoe had been camouflaging industrial lead pollution behind a fast shuffle of posed uncertainties: the extreme range of lead concentrations in soil (neglecting to mention that the high urban values originated from leaded paints and gasolines); the multitudinous natural lead contributions to the atmosphere such as soil dust and meteorite smoke (neglecting to mention that the former contributes less than one thousandth and the latter less than one billionth of the lead in urban air); and atmospheric lead contributions from such things as coal smoke (neglecting to mention the observed one-to-one correlations between automobile traffic, carbon monoxide, and atmospheric lead, and the fact that a coal-smoke tracer, vanadium, is too low by a factor of more than a hundred to indicate significant contributions of lead by coal-smoke).

Kehoe's famous proof of lead equilibrium in the body, obtained by measuring lead in the food and excreta of several men, was shown to be erroneous because he had neglected to measure lead inputs to the body from the lungs, and had assumed that all such lead was excreted without storage in the body (18). A simple case of assuming the conclusion - a rather serious mistake on Kehoe's part, since some of his subjects apparently smoked and had very large lead inputs from the lungs. His assumed conclusions left him in a position unable to explain how his subjects were pertinent to the public at large if they did not have typical body burdens of 200 to 400 milligrams of lead and how they acquired them if they did. It was pointed out that there was no biochemical knowledge affirming the harmlessness of industrial lead circulating through the bodies of polluted people. By merely observing kidney excretion, Kehoe did not prove non-interference with cell metabolism, even if storage did not occur, which, of course it does. It was shown that Kehoe's concept for a threshold of damage was derived from circular reasoning, and that success in reducing the incidence of classical lead poisoning among industrial workers did not constitute proof that the only form of lead poisoning was that defined by practitioners of occupational medicine (17, 18).

The U. S. Public Health Service and the California State Department of Public Health were criticized in my report for refusing to recognize, in their cooperative study with the lead industries, that lead alkyls had elevated the body burdens of lead and the concentrations of lead in the blood of urban Americans,and that existing levels of lead contamination in people were causes for alarm - not complacency.

Public Health officials operate with "facts", just as lawyers and engineers do, and not being scientists, fail (or refuse) to understand that there are no "facts" as they envision them in the realm of science, and that science does not operate to reveal objective truths which will solve human problems dispassionately. This point is admirably illustrated by a sequence of events related to the report issued by "The Working Group on Lead Contamination" mentioned above. Members of the California State Department of Public Health carried out investigations of lead concentrations in the blood of people and in the atmosphere of cities and joined the lead industries in not recognizing that a correlation existed (their 1965 report). In 1966 I prevailed upon the Governor of California to direct the Department of Public Health to re-evaluate their position, and they issued such a report in 1967 (19), in which they reversed their earlier position on the same data and explicitly recognized that lead alkyls are the source of lead in urban atmospheres, and that lead concentrations in the blood of people living in cities are elevated as a consequence. The principal authors of the California report then published their views in a scientific journal in 1967 (20), which resulted in a dispute and polemic with Kehoe (21), their former ally and chief co-author of the 1965 report. The petroleum and lead alkyl industries, in referring to the 1965 joint report, take care to neglect to mention these interesting addenda.

Public health agencies show a dismal lack of leadership, vision, and resolve in defending the public's health, as might be expected, since they are staffed with compromisers, the most successful being those who have displeased the fewest in power. The U. S. Public Health Service did not rush to consider the hazards of lead alkyls, as one might infer from propaganda commonly available. Lead tetraethyl was manufactured and marketed without a twitch from that agency until poisoning scandals associated with its manufacture brought legislative pressure to bear on the service, and it was forced to act (lead alkyls are extremely poisonous in pure form, and the effects on the brains of acutely poisoned subjects induces bizarre behavior that is disconcerting to observe).

Public health agencies are patently unable to conduct evaluative investigations that turn out to be truly defensive of public health. In 1939 the U. S. Public Health Service was involved in an extensive investigation of public health hazards originating from lead arsenate insecticides on apples (22). It concluded that there was no harm to the public at a level of 7 ppm lead in apples (this maximum permissible level is still a regulation today). Kehoe, during this same time, was obtaining data on lead ingestion showing that 1.5 ppm in food should give rise to classical lead poisoning in a matter of months. The conclusions of the Public Health Service were dictated by matters of economy then, and it is likely that they always will be.

My report was printed in a journal that belonged to the forces of occupational medicine and lead industries. This stirred up a hornets' nest of opposition. The furor acted to rally forces opposed to lead pollution, however, and a vigorous, well publicized, controversy ensued both in the U. S. and in Europe (23-25). The reverberations from that controversy and the renewed interest in lead biochemistry which it stimulated was so influential it brought to a close an era, lasting forty years, of the complete domination by industry of the accepted medical views on lead pollution.

Much anguish and bitterness accompanied this transformation. Kehoe's associates in occupational medicine have been outraged by the indignities imposed on a prominent colleague who contributed so much to their field. They recognize that the privileged position of occupational medicine in ministering to public health, which they long enjoyed, is now being seriously challenged, and they fear and resent this. No one wants or hopes for such personal tragedy, but it should be pointed out that tragedy has not been one-sided. The editor of the journal in which my paper appeared was severely criticized for allowing it to be published. Friendships among medical practitioners and researchers in public health agencies and in industry became strained. I have been insulted in numerous publications and on an international scale. The American Petroleum Institute cancelled their support of my research. I am an almost pure end-member of the species Scientist, and yet am regarded as a crusader. Now that is the unkindest cut of all, because, as a consequence, my contributions to constructive and creative aspects of the biogeochemistry of metals and problems of lead pollution are ignored, and my name is confined to degrading contexts in sensational battles.

Will recent advances in knowledge about lead pollution help in its eventual elimination? Hardly. In a recent conference on man's chemical invasion of the oceans, it was made clear that it was not knowledge that governed action on pollution problems, but emotion. Knowledge of lead pollution does lend perspective to man's broader problems, however. The development over the last four and a half thousand years of both lead technology and its associated environmental pollution, from its benign origin to its catastrophic dislocation of ourselves from our animal heritage, is not singular. Instead, it is much like a small, comprehensible, working model of our whole world of difficulties - a world that seems too big and complex to understand - for scientists, at least.

We have developed technology in our world to an unbearable frenzy, and we huddle, overcrowded and terrorized, in national jails, hoping that someone will find a panacea that will banish this unpleasantness. Well, we can see from the example of lead pollution that no help can be expected from industry, our "servant" which provides the paraphernalia we cherish. Nor from the public agencies that are supposed to guard our health and keep our food, water, and air wholesome and free of poisons. What about those saviors of mankind, the scientists?

People want to be deceived by the new whitewash that has been poured over scientists because they are afraid and seeking help, but the centuries old evaluation is still true: scientists are cold-hearted, murderous, egomaniacs. We would all sell our mothers to finance our experiments, and why not, since most of us have had our wives and children in spiritual hock for years, and that's dedication, a noble virtue. Scientists have tiny intellects. Consequently, our philosophy is of the kindergarten variety. We resolve everything our senses perceive into the simplest of abstract forms. The philosophy of science is a name for the activities of some philosophers whose subject is science. It is not meant that that term should dignify the childish faiths of scientists. We are congenitally amoral. Human relations are too complicated and vast to be squeezed into our small minds; therefore scientists subjected to the hazards of people are unable to understand them, and fear them. This made it easy for us to band together and devise a way to roast alive several hundred thousand Japanese civilians twenty years ago. Any normal human, contemplating his part in that hideous crime, would go mad. But we manage to survive, sometimes being mistaken for crusaders, even. Scientists are problem solvers. Not worthwhile _Homo sapiens sapiens_ problem solvers, like creative men in the humanities, but dinky little problem solvers, barely on a hominian level. We are completely hooked, like any common junkie, on the mental orgasms we get from solving our abstract problems. But our activity is revered by others as basic research, and no one, except maybe our wives, wants us to go to Lexington and get the monkey off .

Does this mean that scientists are not specially fitted to solve our lead pollution and other problems? Yes. It is not just that scientists might suggest wrong solutions, for there are no solutions to human problems, and any recourse that is taken will eventually prove wrong, but scientists are congenitally incapable of understanding what to do about human problems. They are not wise. They can only abstract things into inhuman form and discourse on arid problems of relationships among these abstractions. Consider this essay, its subject, and its author. It's a typical scientific product, and it illuminates the unbridgeable gulf that separates scientists from what they may even yearn to do socially.

The barrenness of the scientific intellect does not result from the mere fact that the scientist is a problem-solver, rather, it derives from the nature of his problems and the manner of their solutions. Historians, for example, are also problem-solvers, but they are differently placed on the intellectual scale. Let both the scientist and the historian be presented with, say, a table of data on silver production, wherein annual silver productions of a nation are cited to twelve significant figures. Their reactions will be characteristically different. They are both aware from a standpoint of simple scientific meaning, that the quoted productions are probably not accurate to more than the first two significant figures out of the twelve. The scientist, after closing his jaw which had dropped open in astonishment, will round off the last ten of the twelve figures. The historian is not confined to such a miniscule activity because his larger awareness of human relationships will drive him to seek non-scientific meanings in those last ten not-zero figures. Unlike the scientist, the historian somehow understands beforehand that government bureaucrats do not issue tables of figures for scientific purposes. The scientist believes he understands the meaning of the statement, "The accuracy of my conclusions, which involve annual productions of silver, depends upon the accuracy of the recorded silver production data". But from the historian's vantage this may sound like, "The accuracy of my determinations of the boiling point of water depends upon the accuracy of the water" (26). Consciously or subconsciously, most scientists are aware of their intellectual deformity, and they try to deaden this awful perception with the narcotic of scientific research.

The problem of lead pollution - all of our troubles for that matter - did not originate with our generation. Our troubles evolved, and they will be dissipated by further evolution into even greater troubles. Although this may seem like we are eternally damned for being human, it really means that while we live as a wholesome part of the universe, our understanding of what we are lags behind what we do, so most of us live in ignorant terror.

Three million years ago the biosphere achieved a recognizable means of engaging in overt technology with the evolution of problem-solving hunters. It resided in the power of abstraction by those early Pleistocene man-like apes, and depended simply upon their ability to pause and reflect after sensory stimulation and before responsive action. Possessing the required body structure, they could manipulate their environment at will of their abstract intellect.

The origin of any technology cannot be described in terms of a specific event at a given time, however. It lies buried within the evolving biosphere as a driving force, a spectacular example being the way in which living organisms crept out of the seas, took over the lands, and modified basic geologic mechanisms operating at the surface of the earth. Plants did not just move large masses of hydrocarbons out of the seas onto barren wastelands to transform them into gardens inhabited by animals. They changed the manner in which the forces of weather and streams shifted huge masses of land. They abruptly slowed down the rapid erosion of mountains and for the first time permitted broad elevations of land masses to occur. Because they created soils and greatly reduced the rapid dumping of coarse debris into basins adjacent to mountain chains, they promoted for the first time the long range transport of gigantic masses of fine clays to the open basins of the oceans. This not only greatly altered the character of the oceans and their sediments, but it also modified the role which isostasy had previously exercised in volcanism and mountain building, and so modified the evolution of continents and ocean basins. We cannot look with selective horror upon man's destruction of forests and arable lands, h's extinction of animals, his rape of mineral deposits, and his pollution of the air, seas, and land, for it is an inherent characteristic of the evolving biosphere to try to feed upon and modify the surface of the earth.

But man's tribulations are not just a common manifestation of a long-continued process. He is the precursor of the evolution of the biosphere on an entirely new level. In striving toward new, different forms of technology, the biosphere is now evolving on a non-morphological level amid ramifications and niches of emotion that never existed before. Immersed within that milieu, we have looked back with the arid view of scientists and have described evolution on a morphological level, but we have not yet learned to appreciate the new evolution of anguish on the emotional level.

Capping the fossil record in geologic strata are new additions: increasing concentrations of industrial lead. They do not simply mark new aspects of physical evolution. They signify the probing of life along far more wonderful and terrible avenues of emotion than have ever existed before. The prophets of the world's great religions said it in different, but true, words. In twentieth century terms, technology is the devil within us, the temptation to evil we must try to master.

At least the lead pollution problem may be solved. How? By Oregon wheat farmers and California corn growers. The wheat farmers want the government to build huge alcohol stills, buy the carbohydrate portion of their wheat at cost, and convert it to alcohol, a substitute anti-knock for lead alkyls at no extra cost to the motorist. This would pay for the wheat and the stills and the government would come out even. The farmers would keep the protein portion of the wheat and make a profit from it as feed concentrate. The automobiles would run fine. Since lead alkyls are not made in Oregon and they are poison, while wheat is grown in Oregon and burned alcohol is harmless, there is every reason for the state legislature in Oregon to ban lead and boost alcohol. Oregon can neatly use all it can make. Now, California is right next to Oregon, and is the leading farm state in the nation with a powerful block of farmers. Even more alcohol can be obtained from corn than from wheat. Exposed to Oregon's example, California may succumb, and if California goes - look out Ethyl Corporation! God bless the Oregon wheat farmers. If they can do it, what they do may turn out to be wrong eventually, but it will have been right at the time.

References and Notes

1. S. C. Gilfillan, Jour. of Occupational Medicine 7, 53 (1965).

2. C. Patterson. Data on the history of lead production are taken from an unpublished manuscript in preparation by the author. (1969)

3. T. J. Chow and C. Patterson, Geochim. et Cosmochim. Acta 26, 263 (1962).

4. M. Tatsumoto and C. Patterson, "Concentration of Common Lead in Sea Water", in Earth Science and Meteoritics, Geiss and Goldberg, Eds. (North-Holland, Amsterdam, 1963).

5. T. J. Chow and C. Patterson, Earth and Plan. Sci. Let. 1, 397 (1966).

6. T. J. Chow, J. L. Earl and C. F. Bennett, "Lead Aerosols in Marine Atmosphere", Environmental Science and Technology (in press, 1969).

7. J. Cholak, L. J. Schafer and T. D. Sterling, Jour. of the Air Poll. Contr. Assoc. 11, 281 (1961).

8. Å. Rühling and G. Tyler, Botaniska Notiser 121, p. 21 (1968).

9. M. Murozumi, T. J. Chow and C. Patterson, "Chemical Concentrations of Pollutant Lead Aerosols, Terrestrial Dusts, and Sea Salts in Greenland and Antarctic Snow Strata", Geochim. et Cosmochim. Acta (in press, 1969).

10. J. C. Aub, L. T. Fairhall, A. S. Minot and P. Reznikoff, Medicine 4, 1 (1925).

11. R. A. Kehoe, Jour. of the Royal Inst. of Publ. Health 24, p. 81-97, 101-120, 129-143, 177-203 (1961).

12. D. Elwyn, Scientist and Citizen 10, 53 (1963).

13. U. S. Public Health Service, "Proceedings of a Conference to Determine Whether or not there is a Public Health Question in the Manufacture, Distribution, or Use of Tetraethyl Lead Gasoline", Public Health Service Bulletin 158 (1925).

14. U. S. Public Health Service, "Public Health Aspects of Increasing Tetraethyl Lead Content in Motor Fuel", Public Health Service Publication 712 (1959).

15. Working Group on Lead Contamination, "Survey of Lead in the Atmosphere of Three Urban Communities", Public Health Service Publication 999-AP-12 (1965).

16. A. Cantarow and M. Trumper, Lead Poisoning (Williams & Wilkins, Baltimore, 1944).

17. C. Patterson, Archives of Environmental Health 11, 344 (1965).

18. C. Patterson, Archives of Environmental Health 12, 136 (1966).

19. State of California Department of Public Health, "Lead in the Environment and its Effects on Humans", State of California Department of Public Health (1967).