

## ENVIRONMENTAL ASPECTS OF HEAVY METAL TOXICITY

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The first uses of metals by primitive man marked the beginnings of the technology which led ultimately to the development of modern industry and commerce. During the slow transition from the use of stone to the use of metals various techniques were discovered for the extraction of metals from their native ores, and these crude methods were little improved upon by early civilizations. These primitive techniques made mining an extremely hazardous occupation, and ancient smelting operations must have been particularly deadly due to the dusts and fumes produced. The lead and silver mines at ancient Laurium in Greece contributed greatly to the wealth and prosperity of Athens, but also resulted in furnace fumes which caused men and plants to wither and die in a scene of dusty desolation.<sup>1</sup> The hazardous nature of such work is evident in the frequent use of slave labor<sup>2</sup> and the sentencing of criminals under Roman law to labor in the mines as a form of punishment.<sup>3</sup> Not only convicts and slaves but apparently also the free citizens of Rome were exposed to the toxic effects of some metals. In the latter case the exposure was not the direct result of mining or smelting operations, however. It has been reported that the Romans used bronze cooking vessels lined with lead to avoid the taste given to food by the copper, but that the resulting chronic exposure to the more palatable but toxic lead compounds contributed in part to the deterioration of Roman civilization.<sup>4</sup>

Throughout the development of technology, numerous inorganic chemicals were discovered and studied without regard to any possible harmful effects, and undoubtedly the toxicity of many of these substances was experienced by man long before the effect was related to the cause. Although such toxic substances

have always been present in the environment, they are not often found concentrated in a harmful form in nature. The efforts of man have, however, concentrated certain minerals from widely dispersed deposits into forms which can then be distributed through commerce. The danger inherent in the production and subsequent use of some of these materials has long been recognized, but other metals and their compounds have been introduced by modern technology before the evidence of toxic behavior was fully appreciated. There are numerous examples of the use or misuse of toxic metals during the industrial era, and not unexpectedly, those engaged in the metal processing industries were often the first victims. An historic example is the use of mercuric nitrate in the treatment of furs used to make felt hats of the type worn by Lincoln. This practice resulted in an occupational disease, the hatter's shakes, which was not recognized in this country until 1941.<sup>5</sup> The hatter's shakes actually was a form of mercurialism caused by chronic exposure to mercury during the manufacture of hats from the mercury-treated felt. Since chronic mercurialism first affects the functioning of the nervous system long before other symptoms develop,<sup>6</sup> the character of the Mad Hatter in Lewis Carroll's "Alice in Wonderland" probably portrays the popular image of hat makers around 1880.

The specific problems of the toxicity of metals in industry have been well documented elsewhere, and the excellent reviews by Elkins<sup>7</sup> and Browning<sup>8</sup> are recommended to those with further interests in this area. The review by Browning<sup>8</sup> is particularly thorough and is conveniently organized into a separate chapter for each of the 44 metals surveyed. Other valuable sources of information concerning specific industrial hazards are professional societies, such as the Manufacturing Chemist's Association<sup>9</sup> and the American Chemical Society<sup>10</sup> as well as the various agencies of industry associations.

This review will survey a different aspect of the toxicity of metals. Recent reports have established that metals known to be toxic have been accumulated in the environment which may present a substantial hazard to man. In particular the so-called heavy metals, cadmium, lead and mercury have become widely distributed in the environment within this century through industrial and agricultural applications. Both the extent and the duration of the toxic effects of these metals may exceed the hazards presented by the chlorinated pesticides.

As we have seen above the toxic hazards of heavy metals has long been recognized by industry, but nevertheless there are many examples of the widespread use of these metals in consumer items in modern times which resulted in acute or chronic metal poisoning. An historic example exists in the use of compounds of arsenic in decorative green dyes in items as diverse as wallpaper and confectionery items during the early decades of the last century.<sup>11</sup> Even though arsenic compounds had been known poisons for centuries, the toxic effects of these green dyes went unrecognized for years. Even after production of these items ceased, the arsenic pigments in wallpaper and paints already present in homes continued to exert their poisonous effects.

Within this century a very similar hazard developed which even today causes a serious medical problem among children living in the older sections of our cities. This problem resulted from the use of lead compounds as paint pigments, a practice recognized as hazardous prior to the second world war. But although over three decades have passed, underlying layers of leaded paint in older buildings are ingested by young children, usually between one to five years of age. Children often develop a condition known as pica at this age in which they attempt to chew anything which can be placed in the mouth, even if they are well-fed.<sup>12</sup> Although this poisoned child syndrome was recognized in this country prior to 1960, several hundred cases are treated each year in New York City, and a recent estimate places the total number of cases in the city at about 8,000.<sup>13</sup> Diagnosis is often complicated, however, by the vague initial symptoms of lead poisoning which are often confused by parents as signs of mental retardation or simply accepted as personality disturbances.

This insidious nature of chronic heavy metal poisoning is a serious problem, since the symptoms may develop over a period of years before they are recognized. This factor undoubtedly contributed to the confounding reports of a previously unknown nervous disorder which occurred only among fishermen living on Minamata Bay in Japan. In this case over one hundred cases were diagnosed between 1953-1960 before this malady was demonstrated to be a form of mercurialism.<sup>14</sup> Even though a search had been made for toxic factors on the environment, the presence of mercury was not detected. The source of the mercury contamination in this case was traced to a single manufacturing

plant which had discharged wastes into the bay which contained mercuric chloride used as a catalyst in the production of vinyl chloride for plastics. Although the amounts of mercury in the effluent were not considered harmful, the aquatic life in the bay concentrated the mercury with surprising efficiency. Since the contaminated seafood was a major item in the fishermen's diet, the hazard was eliminated by a ban on fishing in the bay. This meant, of course, that the livelihood of these fishermen was also eliminated, for in 1966 fishing was still banned and mercury remained in the mud bottom of the bay.<sup>15</sup>

The persistent nature of mercury in the environment is due to the chemical properties of an element or atom. Compared to a chemical compound such as DDT it is easy to understand why heavy metals may present a more serious threat to the environment. The so-called hard pesticides are chemical compounds in which the atoms are arranged in a well-defined array by chemical bonds. These chemical bonds in such systems may be ruptured by a moderate energy input which is well within the range of natural forces. Therefore the molecular unit will ultimately be degraded. A similar transformation in the chemical identity of an element or atom, however, requires energy inputs at the nuclear level. That such transformations do not occur is, of course, the historical basis of the classical concept of the atom. Thus elemental poisons are not degraded in nature. The only mechanisms for removal incorporate the toxic element into an insoluble or an inert form which presumably will limit its uptake by aquatic life. But recent evidence strongly indicates that even this does not guarantee that toxic metals carelessly dumped into the environment will indefinitely remain inert.

A recent report from Sweden provided a startling account of the biological conversion of supposedly inert mercury residues by certain anaerobic bacteria into the most toxic of all mercury compounds, methyl mercury derivatives.<sup>16</sup> Organomercurials have long been recognized as extremely toxic substances, and the maximum levels for continuous exposure to the organic derivatives of mercury are generally agreed to be at least an order of magnitude less than for inorganic mercury compounds.<sup>17</sup> Not only are they considerably more toxic, but there exists at present no medical procedure effective in reversing the effects of organic mercury poisoning as does exist in the case of poisoning by the inorganic derivatives. There thus exists a threat to the environ-

ment and man's food supply with very serious consequences, for over 80,000 tons of mercury have been consumed by industry in this country alone since the turn of the century.<sup>18</sup> This figure, though admittedly inaccurate, may be placed in proper perspective by considering that only a few parts per million (ppm) of mercury present in fish taken from Lake Champlain in Vermont<sup>19</sup> and from Lake Erie<sup>20</sup> made them unsafe for human consumption. In fact comparable concentrations were found in the seafood consumed by the Japanese fishermen discussed above.

The low levels of mercury capable of causing detectable injury in man, the insidious onset of symptoms, the irreversibility of these symptoms and the persistence of mercury in the environment have only recently been generally recognized. The Federal government has in recent months instituted legal action against chemical and paper manufacturers to prevent further mercury spillage.<sup>21</sup> A significant point to note is that the amounts average less than about 25 pounds daily per company. Yet there is another route by which mercury has been introduced into the environment which may eventually prove more serious. For some time various seed grains have been treated with organic mercury derivatives to prevent fungus growth in storage, and this application has distributed mercury widely over land areas removed from industrial sources.<sup>22</sup> Recently a spokesman for the National Agricultural Chemicals Association estimated that 80% of all commercial seed in this country is treated with mercury compounds annually, and applications have been made for over 20 years.<sup>23</sup> Although this practice has also been curtailed through government action, only within this year has any attempt been made to survey for possible accumulation of mercury in the environment. The preliminary data reported to date indicate that the contamination is wide-spread, but not enough is yet known to state with certainty that a crisis exists. Nevertheless, the facts appear grim, particularly so because mercury poisoning first affects the very faculties man desperately needs to avoid future errors.

Thus far we have presented only a few examples in which a specific metal of known toxicity was introduced into the human environment through specific uses. In such cases it is comparatively easy to recognize eventually the source of toxicity, although as we have seen, removal of the offending product(s) does not necessarily eliminate the hazard to the environment.

But some metals in the environment have a very basic role in the orderly continuation of life. Although metals were long ago demonstrated to be essential to nutrition in plants and animals, including man, only recently has an understanding of the critical role of these "trace" elements developed.<sup>24</sup> Thus, to understand how it is that a few parts of a toxic metal in a million parts of living matter can so profoundly affect the functions of life, an appreciation of the role of enzymes is necessary.

Enzymes are the catalysts in nature which regulate the rate and direction of biochemical reactions. Only recently has the critical role of trace metals in the mechanisms of biological systems been fully appreciated by inorganic chemists. In part this interest is due to refinements in the theory of metal coordination by various donor groups or ligands. For some time it had been apparent that specific metal ions were necessary for proper functioning in enzyme systems. Research has demonstrated that the biological activity of enzymes may be altered dramatically by the simple substitution of one metal ion for another.<sup>25</sup> The growing interest in this field by biologists as well as inorganic chemists has resulted in the emergence of a new discipline, bio-inorganic chemistry.

Since enzymes are themselves very specific catalysts, the trace metal may be regarded as "the catalyst of the catalyst." The introduction of comparatively small amounts of a relatively simple substance containing the foreign metal ion may bring about a subtle change in an enzyme, perhaps the most subtle change which can be made on an enzyme.<sup>26</sup> And since enzymes themselves are complex substances but present in trace amounts, a very small amount of a metal may have an appreciable effect upon vital processes, such as nerve functions. To understand why the heavier metals are generally toxic, we must delve a little further into their chemical properties.

The metals normally present in biological systems are usually to be found among the "lighter" elements of the periodic table, that is, among those elements with atomic numbers less than 40. Since these metals tend to form the more soluble compounds, they are widely distributed in nature. The metals of higher atomic number generally form less soluble compounds. Hence, they are not readily available to living systems and often are concentrated in isolated geological formations. The heavy metals, therefore, do not appear to be elements essential to proper nutrition.<sup>27</sup>

Thus the introduction of these elements into the environment through the efforts of man has resulted in the widespread distribution of metals not normally present in the environment to any extent. For example, the presence of only several parts per million of mercury in soil represents about a hundred-fold increase over the background levels naturally present.<sup>28</sup> In addition we must consider that man's use of metals may introduce the metal in a form which can enhance its uptake by plants, thereby amplifying the rate and extent to which it becomes further concentrated.

At this point then, a critical survey of other toxic metals in the environment is needed to prevent further contamination from occurring. In order to evaluate the toxicity of a particular substance, certain definitions we have previously assumed will prove useful. A toxic agent in the environment may be considered to be a substance which upsets to some extent the vital functions in an organism essential to man's well-being or to man himself. This definition is admittedly vague and centered on man, and there may be considerable variance in the level and duration of exposure before such effects are apparent, as we have seen. These factors are in turn dependent upon data which is not available, since toxic behavior may not yet be apparent. Nevertheless, there are considerable risks in not anticipating a problem, and there is presently enough conflicting evidence surrounding the continued use of lead to warrant further discussion.

There are two limiting cases in the extent to which a toxic agent disrupts the environment. The more obvious situation exists when the level is comparatively high and the duration correspondingly short before toxic effects appear. The toxicity of mercury in the environment corresponds roughly to this case. That is, specific harmful effects were demonstrated to result from several years exposure to only environmental sources of the toxic agent. In the case of lead compounds used as antiknock agents in gasoline, long term exposure to low levels of lead residues from these compounds is not now an established health hazard. And perhaps not too surprisingly, this point has been used by producers to defend the continued combustion of over several hundred million pounds of organolead compounds in gasoline each year. By now it should be obvious that this type of rather negative evidence may be quickly invalidated. Instead of searches for harmful effects in the environment after they have developed,

evidence that such effects were excluded through rigorous studies beforehand would be comforting.

However, such evidence is extremely difficult to obtain. A recent discussion of chemicals suspected of causing genetic mutations suggested that rigorous proof of genetic damage in man would require a closely controlled population of 20 million studied carefully over 25 to 50 years, if the defect occurred with a frequency of one in a thousand births.<sup>29</sup> Obviously, this approach as a method of detection for environmental hazards would provide only historical insight, since two generations bearing the defect could grow to maturity before this rigorous proof was obtained. However, the opposite, reactionary approach to potential hazards may disrupt and destroy the orderly development of society as alarms are continually sounded but no danger is found.

Therefore we must evaluate potential hazards before they develop based upon the evidence and experience whenever possible. With this attitude in mind let us now survey the arguments surrounding the use of lead anti-knock compounds.

A brief survey of the economics of lead anti-knock compounds will serve to set the scene for discussion of the controversies surrounding their use. Roughly 265 thousand tons of the nation's annual lead production (*ca.* 20%) now is used as organolead anti-knock additives with a market value of 400 million dollars annually.<sup>30</sup> In addition, sales of "scavengers," required to remove the lead deposits from the engine, add another 90 million dollars. The producers of these chemicals maintain that lead is not now a health hazard, that some lead is required or at least naturally present in the diet, and that removal of lead from gasoline might cause more smog.

As we have seen, lead does not appear to be essential in human nutrition, and certainly the levels now present in the environment would greatly exceed such a dietary requirement. We must be careful, however, in relating a physiological disturbance to the mere presence or absence of a particular element without adequate proof. The claim that lead is not now a health hazard must be viewed with some skepticism and even cynicism in the opinion of the author. Recently, a proponent of the harmless nature of dietary levels of lead frequently cited by industry spokesmen was identified as a former medical consultant to a major producer of organolead anti-knock compounds.<sup>31</sup> As mentioned previously, the mere contention that harmful effects have not been demon-



strated is negative proof if the attempts to demonstrate the absence of such proof appear biased. The absence of proved harmful effects was an undoubtedly valid statement that could be made regarding leaded paints during the years that elapsed before the harmful effects became apparent. The simple fact that some uses of lead compounds have led to episodes of plumbism does not, of course, mean that all uses of lead are dangerous. But the evidence appears suspicious, if only because the search for harmful effects has recently begun.

The principal effort of this search has surprisingly been directed toward the relation of lead emission to air quality, although this may be only a tacit admission of the fact that lead residues do not remain in the engine but are continually removed by the "scavengers" and emitted in the automobile's exhaust. The "scavengers" themselves are worthy of note as an environmental hazard. These compounds are always added with the organolead compounds and consist chiefly of dichloro- and dibromoethylene. Upon combustion they form hydrogen chloride (or bromide) which combined with the water vapor also produced are strong acids not likely to prolong engine or exhaust system life.

The studies of lead emissions in relation to air quality are in general agreement that the lead is emitted in particulate form, that is is deposited from the air within several hundred feet of the highway, and that the lead content of vegetation and soil likewise decrease rapidly within this distance.<sup>32,33</sup> Little is known, however, about the ultimate fate of these lead emissions in the environment, and again it appears that the assumption that it is contained in an inert, insoluble form applies. Hopefully, we will not find this assumption invalidated by yet another micro-organism presently at work digesting these inert substances into organolead compounds.

The concern for the distribution of several hundred million pounds of lead annually is based upon the similarity of the toxicity of lead and mercury compounds. Both metals first affect the nervous system, usually long before any other symptoms develop. Often the initial symptoms may be confused with a personality disturbance. Irritability, headache, lack of ability to concentrate, and eventually, loss of coordination, slurred speech, and mental confusion are symptoms typical of chronic heavy metal poisoning.<sup>34</sup> Estimates of the exact level required for the onset of these symptoms vary, as might be anticipated. However such data as have appeared recently suggest that a blood level

of lead above 60 micrograms per 100 milliliters (roughly 0.6 ppm) supports clinical evidence that plumbism is present.<sup>35</sup> The study cited reports data for lead levels in blood among a group of about 80 children studied at the Cook County Hospital in Chicago. Among these children from an area of the city known to have a high incidence of lead intoxication, only about 23% had normal readings of 20  $\mu\text{g}/100\text{ ml}$  or less. Levels indicative of lead poisoning, that is, above 60  $\mu\text{g}/100\text{ ml}$ , were found in about 30% of the children. The range of values found in a control group were 20 to 85  $\mu\text{g}/100\text{ ml}$ , while the study group ranged from 30 to 200  $\mu\text{g}/100\text{ ml}$ .<sup>35</sup> A similar study among adults in California who lived near a major freeway indicated average values of 22.7  $\mu\text{g}$  for men and 16.7  $\mu\text{g}$  for women (per 100 ml blood). A corresponding control group living off the freeway had values of 16 and 9.9  $\mu\text{g}/100\text{ ml}$ , respectively.<sup>36</sup> This study pointed out a fact important in the methods of uptake of toxic metals by humans. That is that the inhalation of very small solid dust particles (less than one micron in diameter) is perhaps the most efficient method for acquiring metal poisoning. This result has also been frequently observed in industrial studies of heavy metals.<sup>37</sup> Thus there does appear to be a health hazard to individuals working in close proximity to heavily travelled highways, and the lead burden in air in major cities may be more hazardous than contamination of the water or food.

Data for the total lead content of air have been widely reported in recent months which suggests such a hazard may be present. Industrial standards set a limit of lead in air safe for continuous exposure at about 100  $\mu\text{g}/100\text{ m}^3$  (micrograms per cubic meter) of air, although there is some dependence on the chemical form.<sup>38</sup> Recent data obtained in San Deigo show average readings in winter of 8  $\mu\text{g}/\text{m}^3$ ,<sup>39</sup> while data for New York City indicate average reading of 7.5  $\mu\text{g}/\text{m}^3$ , and values as high as 25  $\mu\text{g}/\text{m}^3$  were recorded.<sup>40</sup> A proposal by the America Industrial Hygiene Society to reduce the maximum level of lead in air considered safe to 10  $\mu\text{g}/\text{m}^3$  is mentioned in the San Diego report.<sup>39</sup> Although the evidence is not yet complete, it seems that lead in the environment may indeed now be a health problem or rapidly developing into one.

However, the current justifications for removal of lead from gasoline are primarily based upon technical rather than health considerations. The 1971 model year automobiles produced in this country will be engineered to use unleaded gasoline for the

first time since the late twenties.<sup>41</sup> The reason for this change is that the catalytic devices being developed in Detroit which will soon be required accessories to oxidize harmful exhaust emissions become inefficient when used with leaded gasoline.<sup>42</sup> Thus, a conflict has arisen between the interests of the automotive industry and the petroleum industry. Since the addition of lead anti-knock compounds is the least expensive method at present to raise the octane rating of gasoline, and production costs for premium unleaded gasoline are thus higher, the petroleum industry must make significant and expensive alterations in the refining process. Hence, there is obvious reluctance on the part of this to convert profitable operations unless the added costs are accepted by consumers. Therefore, an interim period in which both leaded and unleaded fuel will be available may do little to prevent lead pollution. It is unlikely that, given a choice, most motorists will consistently buy the unleaded gasolines at premium prices as long as leaded gasolines are commonly available. An alternative approach is developing, however. Major refineries have recently introduced so-called low-lead gasolines which contain roughly one gram of lead compared to the present two to three grams per gallon.<sup>43</sup>

This compromise, however, appears based wholly upon economic considerations. The mounting evidence is that lead is already present in the environment and that the claim no health hazard presently exists is questionable. Both factors strongly suggest that the public also has a vested interest in the continuing sale of any leaded gasoline.

It must be pointed out that there are also other sources of lead less extensively distributed which may contribute significantly to the lead burden in specific areas. Lead storage batteries contain several pounds of lead which may enter the environment through careless handling, in disposal and lead reclamation operations. The lead metal has some salvage value and hence old batteries are broken open and the lead plates removed for reprocessing. Browning<sup>8</sup> cites a report by Gillet<sup>44</sup> of an outbreak of lead poisoning among children in Rotherham, England, in 1954, due to the use of discarded battery casings as domestic fuel. Obviously this is not likely to occur often, but currently there are well over 100 million motor vehicles using lead storage batteries. The disposal of junked automobiles presents a formidable problem in itself, and the disposal of discarded lead batteries deserves special attention. As we have seen, toxic levels of heavy metals in the

environment are measured in parts per million. Thus 10 pounds of lead from a single battery when mixed with one million pounds of soil (or air or water) represents 10 ppm. Thus the careless disposal of discarded batteries and lead reclamation operations in municipal areas presents yet another lead hazard. Finally, it should be mentioned that although leaded paints cannot legally be used in the manufacture of children's furniture and toys, no such restriction applies to paints intended for other use. The marketing of lead-containing paints in pressurized spray cans therefore presents a dual hazard to the consumer. Not only may these paints be used inadvertently in areas frequented by children, but the spray application can expose the user to lead-containing dusts. Elkins<sup>7</sup> stresses that inhaling lead dust is a most efficient route to chronic lead poisoning, even if the dust is in the form of an insoluble compound. Few consumers would recognize chrome yellow, a common yellow pigment in paint, as a synonym for lead chromate. Yet a nationally distributed anti-rust paint contains 11% chrome yellow without any explicit warning of the lead hazard. Other examples of leaded paints as well as other potentially toxic pigments have been observed by the author in the Boston area without any warning beyond the mention of solvent hazard. Perhaps the increasing incidence of lead poisoning among children is not due merely to old underlying layers of paint. It should be noted that children suffer the toxic effects of lead much more acutely than adults similarly exposed.<sup>45</sup>

Although the toxic effects of lead and mercury in the environment have now been generally recognized, another heavy metal widely used in industry and numerous consumer goods can exhibit toxic behavior. Cadmium is a metal very closely related to zinc and mercury in its chemistry. Since zinc is essential in nutrition while mercury is toxic, the intermediate properties of cadmium deserve mention. Cadmium occurs in nature with zinc combined with sulfur, and most commercial grades of zinc contain small amounts of cadmium as an impurity (*ca.* 1–2%). The chemistry of the two elements is so similar that separation must be effected by a physical method, distillation. Although it may appear strange at first encounter, zinc and cadmium are normally refined by distillation at their normal boiling points of 907° and 767° C, respectively.<sup>46</sup> Since cadmium is slightly more volatile than zinc (*i.e.*, lower boiling) it can be separated from zinc by distillation on an industrial scale.

For some time, cadmium has been recognized as a serious

hazard in industry, but this fact has received little attention elsewhere. Elkins,<sup>7</sup> for example, states that as an acute poison, cadmium ranks with the most toxic fumes and gases, and that its effects are similar to those of phosgene, consisting mainly of injury to the lungs. Browning<sup>8</sup> cites a 1957 study that noted cadmium has probably more lethal possibilities than any of the other metals.<sup>47</sup>

Acute poisoning by cadmium is fortunately uncommon, but the possibility of chronic cadmium poisoning has only recently been recognized.<sup>48</sup> Again, the metal and its compounds were first used extensively within this century before the toxic behavior was fully appreciated. Cadmium has been commonly used as a rust preventive plating on hardware items for five decades.<sup>49</sup> It now appears likely that previous reports of the toxicity of zinc platings and alloys such as brass were due at least in part to the presence of cadmium.

The chronic effects of cadmium have not been studied as intensively or for as long as in the case of lead or mercury. However, it has been well established that cadmium in the diet may displace essential zinc and result in serious physiological disturbances. In particular zinc is essential to the normal functioning of the male reproductive tract, and studies with laboratory animals have shown that cadmium in the diet can displace zinc from the male reproductive tract and result in lowered fertility and even atrophy of the male sex organs.<sup>50</sup> Since cadmium is so similar to zinc in its chemistry, the system is apparently unable to discriminate between zinc and cadmium. Yet zinc is essential while cadmium is toxic.

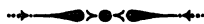
Similar studies have demonstrated another effect of chronic cadmium poisoning. Replacement of zinc in the diet by cadmium has been reported to cause symptoms in laboratory animals indistinguishable from certain types of heart disease.<sup>51</sup> Although this effect has not been demonstrated clinically in man, a recent study showed that a correlation exists between the national incidence of heart disease and the consumption of zinc, presumably a result of its cadmium content.<sup>52</sup> More significantly, the incidence of heart disease did not correlate with any other factor considered by these authors.

Although the current evidence linking cadmium consumption to male fertility or the incidence of heart disease are matters deserving further serious study, conclusive clinical confirmation of these relationships has not yet appeared. In any event, cad-

mium metal vapor and dusts containing cadmium compounds are well known to be harmful, and certain localized hazards present in certain consumer items should be pointed out. Foodstuffs in contact with cadmium plated articles have been found to cause acute illness.<sup>53</sup> It is possible that some episodes of food poisoning have been caused in this manner, since the chief symptoms are those of gastrointestinal upsets. It is not too difficult to conceive of the use of cadmium plated hardware in consumer items such as barbecue grills or kitchen ware.

The recent wide-spread use of rechargeable nickel-cadmium alkaline batteries in a variety of products may also become a source of cadmium exposure to consumers. In this respect it may be noted that Browning<sup>8</sup> refers to some fatal cases among Swedish workers engaged in the battery industry after 3 to 9 years had elapsed since their employment.<sup>54</sup> This same author remarked that it should be borne in mind that cadmium will remain for a very long time once it has entered the body.

Throughout this review an attempt has been made to summarize the symptoms and ultimate effects of chronic metal poisoning, and also the basis of the insidious onset of these effects. Obviously, there are numerous examples of toxic effects from other metals and their compounds other than those of cadmium, lead, and mercury. However, these three metals appear to present significant hazards to man and his environment if indiscriminate use is continued. It is essential that federal and state legislatures begin to consider these hazards and to take appropriate action. It is hoped that some insight into the specific nature of toxic metal hazards in the environment has been developed by the examples chosen. The author acknowledges that other opinions concerning the seriousness and extent of certain of these hazards do exist, and he hopes that the current concern results in discussion which will ultimately benefit man instead of men.



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