

The Health Dangers of Lead in Drinking Water

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Summary

The author presents a survey of the controversial opinions regarding the health effects of lead and criticizes Kehoe's thesis that the upper safety limit for blood Pb is sharply defined at 80 $\mu\text{g}/100$ ml blood on the basis of the cybernetic toxicology of Lehnert, the thesis of Fruentov on the functional accumulation of lead effects and other publications. In experiments sperm damage has already been induced with extremely low lead doses, which are considerably exceeded by present lead intakes of human beings from food, drinking water and the other sources. This damage induces functional disturbances in the offspring, and these have increased very much since 1950 in the Federal Republic of Germany in the era of remotorization after World War II. In view of the synergism of lead and polyphosphates which find their way into drinking water in excessive quantities today, it is doubtful whether the WHO safety threshold protects even against the physiopathological effects of lead. Andrologic and cytologic tests are necessary in the drinking water of all water supplies, with a eugenic aim in view.

I

In February, 1970, speaking of a comprehensive program for a healthy environment, the President of the USA called for an end to the addition of lead alkyls to gasoline. The Government of the Federal Republic of Germany is likewise pressing for the prohibition of gasoline leading. Since 1959 the Soviet Union has forbidden the delivery of gasoline containing lead in many large cities when the safety limit for the concentration of atmospheric lead dust had been exceeded.

While the decisions in the USA have aroused interest all over the world, the discussion started in Great Britain on the question of lead in drinking water has hardly penetrated beyond that country. The knowledge that the safety threshold set by WHO (0.05 mg Pb/liter drinking water, with the possibility of higher readings in water drawn in the morning) has been exceeded many times over also in drinking water, makes it necessary to examine this question in other countries,

too. At a time when the amount of lead the public is exposed to, due to the leading of gasoline, is already leading to preventive measures costing billions, other sources of lead also gain in importance.

While the Soviet safety threshold for atmospheric lead dust (MIC value) is soundly based, both experimentally and medically (Stöfen, 1968), Nixon and the Bonn Government have forgone any medical basis for their appeals and preventive measures. Since Zangger (Zürich) and Bersin (St. Gallen) have passed on, there are only a few competent scientists to be found outside soviet writings who consider the leading of gasoline serious or reject it altogether. Among these are Lehnert (Erlangen 1970), Hardy (Cambridge, Mass., 1966) and Danielson (Solna, Stockholm 1966). Only the high deposit of dust on foliage plants on both sides of the highway is generally recognized as dangerous.

The leading of gasoline is defended above all by Kehoe (Cincinnati 1968), Högger (Zürich 1966) and by the Swiss Federal Commission for Air Hygiene (Anonymous, 1968); the work of Haley (Honolulu 1968) should also be mentioned. The question of lead in drinking water is, of course, the more critical, the smaller the safety margin left by the other lead sources. Although the safety threshold for lead in drinking water has not been criticized up to now, a survey of the various views held about the danger, respectively harmlessness of lead incorporation seems appropriate.

In 1968 Kehoe repeated his view that the safety zone of lead effects is sharply defined by the blood lead level of 80 $\mu\text{g}/100$ ml. Leading researchers in industrial medicine from different countries who met in Amsterdam in 1968 to determine rules for the assessment of the various tests used in the diagnosis of lead poisoning, expressed the same opinion (Lane et al., 1968). Beside blood lead levels

of 40 to 80 $\mu\text{g}/100$ ml the following are considered tolerable according to those authors:

80 to 150 μg Pb/liter urine

150 to 500 μg coproporphyrin/liter urine

6 to 20 mg δ -aminolevulinic acid/liter urine.

If the signatories of these theses are asked for a scientific basis, they direct the questioner to the work of *Zielhuis* (Amsterdam 1969). According to this study the blood lead level forms the central point of the proceedings in Amsterdam too. The opinions about the permissible limit vary between 60 and 80 $\mu\text{g}/100$ ml blood. At *Kehoe's* suggestion 70 $\mu\text{g}/100$ ml blood was agreed upon. The conference held the view that if the western limit for lead dust concentration at the place of work (0.15 mg/m³) is observed, blood lead levels of more than 70 $\mu\text{g}/100$ ml blood do not occur.

Zielhuis does not comment on the question of insidious lead poisoning.

In the theses (*Lane et al.*, 1968) it is asserted without any proof that some mild symptoms which occur with blood lead levels of 40 to 80 $\mu\text{g}/100$ ml "are not attributable to lead". According to the theses the list of these mild symptoms includes:

tiredness

lassitude

constipation

mild abdominal complaints or pains

altered sleep

irritability

anemia, pallor

diarrhea

nausea

If one looks further for a scientific substantiation of these views, one must state that *Tomashetski* and *Mitchell* (Columbus, Ohio, 1966) dealt with this question at the symposium of the U.S. Department of Health,

Education and Welfare in November 1965, but they reached conclusions which one can only describe as careful but vague. On the same point *Kehoe* refers to his publications of 1934, 1959 and 1963 and to unpublished data without touching even briefly on their content. Even in his study published in 1963 *Kehoe* does not provide any basis for the assertion that the effects of lead only begin with a blood lead level of 80 $\mu\text{g}/100$ ml upwards. In 1959 the publications about the ALA test were not yet available: for the rest we refer to *Danielson* (see below).

Haley (see above) does not deal with insidious lead poisoning. His surprising statements about the particle size of lead dust from car exhaust fumes have been corrected by *Lee et al.* (Cincinnati 1968).

In a hearing before the Commonwealth of Pennsylvania on the question of the safety threshold for atmospheric lead dust *Kehoe* (1968) described experiments with two persons who were exposed for up to 37.5 to 40 hours to 0.15 mg Pb/m³, when the blood lead level rose, but did not rise with 0.01 mg/m³.

Högger (Zürich 1966) likewise rejects the idea that the population is endangered by the leading of gasoline. He considers the safety zone of lead effects as sharply defined threshold for lead dust at the place of work and the actual lead dust concentration to be adequate. The blood lead levels of garage workers have certainly risen from 33.3 to 37 $\mu\text{g}/100$ ml from 1949/50 to 1963, but still remain below the critical range according to the Amsterdam theses.

The cybernetic toxicology of *Lehnert* (Erlangen 1968) opposes above all the views of *Kehoe*. According to this, the blood lead level is not at all decisive in cases of lead poisoning, but the dynamics of the endogenic and exogenic lead affluxes. The blood lead level is at most significant in so far as endogenic lead affluxes are more frequent with

higher blood lead levels than with lower levels. Moreover, a sufficient number of publications report "classic" examples of lead poisoning with lower blood lead levels than 70 or 80 $\mu\text{g}/100\text{ ml}$, e. g. the work of *Holmquist* (Sweden 1960). *Hopkins* (London 1970) regards the opinion that there is a blood lead level at which, when exceeded, lead poisoning occurs as dubious, on the basis of experiments on baboons. *Teleky* (New York, formerly Düsseldorf, 1955) "saw workers who, after working for decades as solderers, file-cutters etc., fell ill with paralysis or serious vascular and kidney disorders, but amnestically mentioned nothing more than a lead colic in the first year of working with lead". The frequently emphasized importance of clinical symptoms for the diagnosis of lead poisoning therefore becomes doubtful. The view of *Fruentov* (USSR 1961) of the functional accumulation of the effects of lead, which also occurs even when the incorporated lead is rapidly excreted, is not yet well-known in the West. After every incorporation a trace reaction remains. In experiments he was able to poison cats fatally in 60 to 70 days by daily subcutaneous injections of lead carbonate or lead sulphate, without the blood lead level rising. Death was due to bulbar paralysis.

Diagnostically superior to the determination of the blood lead level is the measuring of indirect criteria of lead absorption, namely the porphyrin test and the δ -aminolevulinic acid test (ALA test); this latter is superior to the porphyrin test (*Lehnert* et al., Erlangen 1969), cf. the work of *De Bruin* and *Hoolbom* (Amsterdam 1967). According to *Lehnert* (1968) ALA excretions of more than 3 mg/day are clearly pathological as regards lead effects; of course a higher ALA excretion also occurs in rare diseases like porphyria. *Lehnert* bases his threshold value also on *Heilmeyer* (Ulm) and *Gattner* (Freiburg i. Br.). According to *Bersin* (St. Gallen 1966) nerv-

ous disorders are found with excretions of 2 to 3 mg/day. *Koumidis* (London, 1963) reports that psychically disturbed children excrete 0.38 mg ALA/100 ml urine (healthy children 0.2 to 0.26). The latter values would correspond approximately to *Lehnert's* limit value (3.0 mg/day for adults). Moreover, *Koumidis* reports that these mentally disturbed children can be cured by lead elimination. *Gattner* (Freiburg i. Br. 1965) has indeed raised his safety limit in the meantime to 4 mg/day, but with this still remains below the upper limit of the norm according to the Amsterdam studies (6 mg/l or 6 to 9 mg/day). The Swiss Federal Commission for Air Hygiene obviously also relies on these values when it considers excretions of 3 to 5 mg/l in Basle policemen as not serious. By definition a "norm" designates only de facto values not pathological limit values; it may lie within the pathological sphere. The rapid increase in functional-degenerative diseases does not support the view that health represents the normal state.

Zykova (Moscow 1952) ascertained in the zone of waste gases from lead works with an average lead dust concentration of 2,2 $\mu\text{g}/\text{m}^3$ an eightfold increase in nervous and gastrointestinal diseases in men of 18 to 50 years and a doubling of heart and circulatory diseases. *Gusev* (Ryazansk 1961) a higher coproporphyrin content in the urine of children from a kindergarten, under similar conditions with 1 $\mu\text{g}/\text{m}^3$. *Lane* (1964) and *Dingwall-Fordyce* (1964), both Manchester, indicate a higher mortality due to cerebral hemorrhages and kidney disease in workers exposed to lead. The most comprehensive survey of clinical illustrations of lead poisoning is given by *Stöfen* (1970).

The thesis that occupational and extra-occupational exposures to lead remains within tolerable limits is extremely uncertain. The school of *Kehoe* has not attempted to refute the work of *Lehnert*, *Hardy* or *Zykova*. Da-

nielson (Solna, Stockholm, 1966), on the other hand, has worked through the entire publications of *Kehoe* over a period of 18 months and in the most important of them pointed out fundamental mistakes in the evaluation of the experimental results and in the conclusions. Altogether "the works of *Kehoe* have thrown no light on the lead problems" (*Danielson*).

Kehoe has not concerned himself at all with the effects of lead on the psyche, and industrial medicine as a whole but little. *Hagen* (Düsseldorf 1968) finds criminality to be an effect of serious lead poisoning. According to Soviet studies the psychical effects reveal themselves before the physiological. Such differences become more likely by the fact that lead inhibits the synthesis of nucleic acid and proteins in which the genus memory and the individual memory are stored. The damage, caused by lead exposure of the parents, in their offspring begins even before the effects on the psyche (*Egorova* et al., Moscow 1966), *Muro* and *Goyer* (Chapel Hill N.C. 1969) report that experiments show chromosomatic aberrations caused by lead; *Schwanitz* et al. (Erlangen 1970) found cytologically a higher percentage of mitoses with secondary chromosomatic aberrations in workers exposed to lead. The percentage of these mitoses rose with the ALA excretion in the urine. According to *Muro* and *Goyer* the pathology of lead poisoning is connected with the metabolism of the nucleus; according to *Oelmann* lead can penetrate into the nucleus (Göttingen 1964). Even more disquieting is another aspect of lead, the germ damage caused by it, which is associated with functional disorders in the offspring. In the USSR andrological research in industrial medicine has been engaged in for at least five years. According to *Sanotskii* et al. (Moscow 1969) mutation and malformations have inferior importance beside the functional disturbances caused by the poi-

son. Germ damage occurs even with extremely low lead doses (0.002 mg/kg body weight 6 times in 10 days) (*Egorova* et al., Moscow 1966); *Golubovich* et al. (Moscow, 1968) confirm this conclusion and at the same time provide numerical data about the effects. *Stöfen* (1969) calculated that these amounts of lead are exceeded 50 to 100 fold in grazing cattle, and had the suspected sperm damage confirmed by an insemination station. *Kasbohm* (1965) reports that ovarian disorders in cattle have increased. *Tyler* (1953) has ascertained that the life-span of the sperm of many animals living in the open increases considerably when the lead is removed from the parents with edetate. It has been proved that the lead dust from car exhausts covering the world including the Antarctic is washed out of the atmosphere with the precipitates. According to the figures of *Lehnert* et al. (1969) which are in no way exaggerated, the normal lead intake in food and drinking water in the Federal Republic of Germany amounts to 0.512 mg/day or about 0.007 mg Pb/kg body weight and day, and therefore probably lie within the sphere of germ damage with functional effects. In fact the functional disorders in young people are increasing in a frightening way, precisely since 1950 in the wake of remotorisation, e. g. youth criminality (*Hellmer*, Kiel 1969) and indeed in the Federal Republic more markedly than in the less motorized German Democratic Republic. The top values of lead intake lie much higher, there are, for example, wines with a lead content of 0.6 mg/l.

If one draws the conclusions from these statements, the result can only be that not only the production of lead alkyls must be restricted but the production of lead altogether, except a small amount for installations to screen against ionizing rays. Certainly, lead is in many cases only a by-product in the smelting of other ores.

The question of whether lead inhibits the assimilation of plants does not seem to have been sufficiently studied yet. Only the work of *Huffaker* and *Wallace* (1959) is known to the writer, according to which Pb inhibits the dark fixation of CO₂ in homogenates of citrus leaves. *Keller* and *Zuber* (Birmensdorf, Switzerland, 1970) too treat this problem.

II

Whereas in some countries the necessity of forbidding the leading of gasoline is clear, the opinion regarding lead in drinking water, namely that it no longer presents a risk, is prevalent in expert circles. Does this view stand examination?

Without doubt spring water and underground water can be found with a geochemically high lead content. When new springs are tapped, the lead concentration is determined to exclude water containing excessive quantities of lead from the waterworks supply. It is possible that no such test was carried out on springs which were in use before the institution of these tests. The rotational tests of drinking water by the Chemical Examination Boards in the Federal Republic of Germany do not include the determination of lead concentration.

Although the quantities of lead in the precipitations at present sometimes exceed the WHO safety threshold because of the absorption of lead dust from automobile exhausts etc. (*Ettinger*, Cincinnati 1967) the lead concentration in running water is as a rule not high because of an absorption of lead by ground particles and an ion exchange in the seepage of the precipitations and in the running which lead to an elimination of the lead (*Patterson*, Pasadena 1965). *Barmes* (Geneva 1968) reports that the lead content of the Sepik river in New Guinea varies according to water level and na-

ture of the subsoil, without, however, being able to trace the causes of the changes.

When drinking water passes through household water pipes made of lead an increase in lead content can again occur according to the composition of the water, above all when the pH value is below 7.0 or above 9.8. But even with pH values between 7.0 and 7.8 plumbosolvency is possible. This also depends on the chemical composition. For example, *Wilson* (Innerleithen, Scotland, 1967) reports that the lead content in drinking water was very high (up to 1 mg/l) after heavy rainfall. In such cases the river water turned brown. The author found organic acids in the sediment on the river bed which must have lead to a higher plumbosolvency in the households with lead piping. Humic and fluvic acid lead salts from organic material could, according to *Wilson* be transformed to lead chloride by dissolute hypochloric acid in London water systems. The polyphosphates, which according to *Becker* (Berlin 1970) are added in excessive quantities to detergents and to many foods and so find their way into drinking water, increase the danger of plumbosolvency (*Buydens*, Brussels 1957). Within the organism they show in addition synergesis with lead (*Becker*, Berlin 1970). According to *Naumann* (Berlin 1962) the water-works are able and obliged to avoid plumbosolvency of their water by adequate regulation of its chemical composition. But these regulations are sometimes unknown to the water-works, as observed by the writer, and can hardly have taken note of the synergesis of Pb with polyphosphates. In the waste-water purifying plants lead elimination again takes place (*Nosbers*, Bonn 1968). It cannot be asserted, it is true, that in the water-works along the Ruhr which are connected in series the lead levels rise from plant to plant, but the polyphosphate content must increase, a circumstance which appears serious.

In the German Empire before the First World War, the kingdom of Württemberg and the Grand Duchy of Hesse forbade the installation of lead household water pipes, Prussia and Saxony, however, did not. Switzerland took this step in 1960. The air raids of the Second World War have increased the number of houses with lead water pipes in Germany. Since then lead water pipes are hardly ever installed, without a prohibition on them having been issued. In Spain lead pipes are still installed today, as observed by the writer. *Naumann* (Berlin 1962) has published a list of mass poisonings caused by lead in drinking water in the German Empire. Statistics are available about the pH value of most of the water-works in the Federal Republic of Germany (*Anonymous*, 1959).

Newer material about a connection between the lead content of drinking water and characteristic values which mark lead effects would seem to exist only in a very small quantity. *Wilson's* work (Inverleithen 1960), which is scientifically not very exacting, about a correlation of the lead content in drinking water with coproporphyrin excretion in urine can be mentioned. It is generally known in the USA that a positive correlation exists between hardness of water and heart and circulation disease mortality; the obvious conclusion that the plumbosolvency in lead pipes is decisive in this has not been checked as far as the writer knows. It must be said that in the USA internal medicine is less open to the idea of such a connection than in Europe. *Hardy* (Cambridge, Mass., 1966), for example, does not mention heart and circulatory diseases in her survey on the pathological effects of lead.

As far as prophylaxis is concerned, the necessity of observing the safety threshold suggested by WHO or the national one cannot be doubted. As a first step, the introduction of lead analyses of the drinking

water from houses with lead piping is necessary, but also the water provided by the waterworks should be tested at least once. If a higher lead content is discovered during the tests, replacement of the lead pipes with pipes of a different material seems unavoidable, difficult though that may be under some circumstances. Public regulations with this aim in view may well come up against legal difficulties in old houses which have been approved by the authorities. The possibility of letting the morning water run off remains to the drinking water user, or of changing to mineral water, about whose lead content information can be obtained. Of course, the question presents itself of whether the details given on mineral water bottle labels still correspond to the facts. Many mineral water concerns have been forced to tap new springs because of changes in the subsoil water level. The question of whether the partial contamination of the subsoil water has affected the mineral water has not yet been examined. Some related questions put by the writer to competent authorities were not answered.

Leclerc (Lüttich 1962) gives a survey of the various circumstances which can produce plumbosolvency. Mentioned are higher water temperatures, various materials used in the installation of household water systems with the result of corrosion through electric currents, connection of earthing conductors to the lead piping, among other things. The use of water from flow-type heaters also seems dubious.

However, the question must also be asked, if only because of the synergism with the polyphosphates which are pouring in massive quantities into the biosphere, whether the safety threshold suggested by WHO for lead in drinking water protects adequately against the physiopathological effects of lead. The effects of mercury and lead add to each other at least (*Fridlyand*, Moscow 1965).

If we want to make the biological future safe, a continuous andrological or cytological testing of all drinking water in every water-works with eugenic aims is indispensable.

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