HEAVY METALS

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1. INTRODUCTION

Increasing industrialisation has been accompanied throughout the world by the extraction and distribution of mineral substances from their natural deposits. Following concentration, many of these have undergone chemical changes through technical processes and finally pass, finely dispersed and in solutions, by way of effluent, sewage, dumps and dust, into the water, the earth and the air and thus into the food chain.These include metals and thus also the heavy metals relevant for this document.

Together with essential nutrients, plants and animals also take up small amounts of contaminant heavy metal compounds and can concentrate them. As certain heavy metals such as lead, cadmium and mercury have been recognised to be potentially toxic within specific limiting values, a considerable potential hazard exists for human nutrition.

Not all the traces of heavy metals in plants and animals are the results of human activity. Some arise through the absorption processes of naturally occurring soil components, as has been shown for cadmium in particular. Purely theoretically, every 1000 kg of "normal" soil contains 200 g chromium, 80 g nickel, 16 g lead, 0.5 g mercury and 0.2 g cadmium! Therefore it is not always easy to assign a definite cause for an increased heavy metal content. Even foodstuffs produced in completely unpolluted areas are not entirely free of heavy metals. The absorption of very small amounts is therefore unavoidable in principle and has always occurred. As a result, the Codex Alimentarius is busy with the preparation of standards for heavy metals in foodstuffs among others.

Explanation of symbols and units of measurement:

Pb = Lead	1 g = 1 000 mg
Ni = Nickel	1 mg = 1 000 µg
Cd =Cadmium	1 ppm = 1 mg/kg
Hg =Mercury	1 ppb = 1 µg/kg
Cr = Chromium	

2. Definition

Those metals are described as "heavy metals" which, in their standard state, have a specific gravity (density) of more than about 5 g/cm^3. Some of them, such as copper, nickel, chromium and iron, for example, are essential in very low concentrations for the survival of all forms of life. These are described as essential trace elements.

Only when they are present in greater quantities, can these, like the heavy metals lead, cadmium and mercury which are already toxic in very low concentrations, cause metabolic anomalies (see chapter 4.4). Here, the boundary between the essential and the toxic effect is somewhat problematic.

There are 60 heavy metals. These also include the precious metals platinum, silver and gold. For this report, however, only the smallller group of toxic heavy metals is of significance.

3. The context of the heavy metal problem

Essentially, the heavy metals have only become a focus of public interest since analytical techniques have made it possible to detect them even in very small traces. The relatively reckless handling of heavy metals and their compounds in former times can partly be explained by the fact that their effects were unknown. Today, analytical detection is possible down to a thousandth of a mg/kg for certain matrixes.

This has made it possible for toxicologists, in animal experiments, to follow up the effects of individual substances down to the smallest concentrations. Their warnings, particularly with regard to the effects on health of chronic consumption and the accumulations to which this leads, have startled the public and, at times, mostly as a result of the activities of so-called pressure groups, have generated genuine hysteria.

All this has taken place against the background of a steady increase in the processing of all types of heavy metals in industry and the household. Therefore, proper disposal, recycling and the regulation of the application of sewage to agricultural land, have assumed great importance.

4. The toxic heavy-metals

4.1 *Lead*

4.1.1 The origin of lead in foodstuffs and their surroundings

Lead has been mined since ancient times and has been processed in many ways, e.g. for water pipes, containers and, as acetate, even for sweetening wine ("lead sugar").

World production amounts to millions of tons and is used in the manufacture of accumulators, solders, pigments, cables and anti-rust agents (red lead/lead oxide) and, a considerable amount still, into anti-knock petrol.

The main sources of lead pollution in the environment are: Industrial production processes and their emissions, road traffic with leaded petrol, the smoke and dust emissions of coal and gas-fired power stations, the laying of lead sheets by roofers as well as the use of paints and anti-rust agents.

Problems for foodstuffs were caused for a long time, and are still caused today on occasion, by the soldered seams of cans and the soldered closures of condensed milk cans, the metal caps of wine bottles and, still, by lead pipes in drinking water systems.

4.1.2 Toxic effects

Lead can trigger both acute and chronic symptoms of poisoning. Acute intoxications only occur through the consumption of relatively large single doses of soluble lead salts.
Chronic intoxications can arise through the regular consumption of foodstuffs only slightly contaminated with lead. Lead is a typical cumulative poison. The danger of chronic intoxications is the greater problem.

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Basically, as a result of their comparatively high affinity for proteins, the lead ions consumed bond with the haemoglobin (red blood pigment) and the plasma protein of the blood. This leads to inhibition of the synthesis of red blood cells and thus of the vital transport of oxygen. If the bonding capacity here is exceeded, lead passes into the bone-marrow, liver and kidneys. Such an intoxication leads to:

- Encephalopathies in the central nervous system (CNS);
- Disturbances in kidney and liver functions progressing as far as necrosis;
- Damage to the reproductive organs;
- Anaemias and many metabolic deficiency symptoms.

Some of the injurious processes are still not properly understood. Particularly dangerous to all forms of life are the organic lead compounds. They cause injuries to mental development such as reduction of intelligence, growth disturbances and spasticity. Children are particularly at risk from lead consumption, both before and after birth, as they absorb lead more rapidly than adults. Particularly affected are small children, with their habit of placing dirty fingers and objects of all kinds into their mouths or licking them (so-called mouth/hand activity) and, in this way, swallowing dust and soil particles containing heavy metals, for example from lead-based paints.

In animal experiments, the consumption of domestic and surface dust leads to a measurably increased heavy metal content in the blood. Little is known about the excretion of lead, once it has been absorbed. The greatest part accumulates in the body. Lead is not considered to be a carcinogen or mutagen.

4.1.3 Present contamination of foodstuffs and acceptable maximum levels

In 1993, the joint FAO/WHO Expert Committee for Additives and Contaminants (JECFA) reduced the value it had provisionally specified for adults in 1972, for tolerable lead consumption per week (PTWI - provisional tolerable weekly intake), from 0.05 mg/kg body weight to 0.025 mg (or 25 μg).

This value represents the upper limit, for consumption quantities over prolonged periods, still to be regarded as tolerable. Short-term excess consumption is accepted if the average value for consumption over a long period is not exceeded.

The reason for the reduction which has now taken place is, firstly, that research has revealed further harmful potentials in lead and, secondly, that lead contamination has decreased throughout the world. Originally this PTWI was intended only to apply in the case of children.

The foodstuffs which contribute most to the consumption of lead are vegetables, fruit, drinking water, beverages and cereal products. Compliance with the PTWI values of the JECFA can best be established by a study of the so-called food shopping basket. This is composed, according to country, of the various foodstuffs normally purchased in one week. An average value for them all is determined analytically. For details of a monitoring system which has been introduced throughout the world see chapter 5.

It is reported that in individual cases in some countries the PTWI value for lead in fruit and vegetables was exceeded, but not that for the "shopping basket". Fruit and vegetables mostly acquire their contamination through impurities in the air. Accordingly, they can be decontaminated to a large extent by simple washing. Since lead has been eliminated from petrol, the lead content has fallen sharply in many cases.

The lead content in drinking water presents a problem in many countries. Thus, the present WHO guideline of 50 μg/l is exceeded in Great Britain, for example, in 34 % of households.

4.1.4 The situation with regard to raw materials for confectionery

Cocoa, milk, fats, flour and especially sugar neither belong to the highly contaminated foodstuffs, nor are they consumed in large quantities. Therefore they make little contribution to the total contamination of the "shopping basket". In the draft Codex Paper "Standard for Lead in Foods", therefore, they are not considered, but a document does exist which includes some of these materials (CX/FAC 95/18).

4.2 *Cadmium*

4.2.1 Origin of cadmium in foodstuffs and their surroundings

Cadmium (world production in 1972, 15 000 t) exists in low concentrations in all soils. It is actively extracted from its ores for commercial purposes and is also emitted in industrial processes such as metal melting and refining, coal and oil-fired power stations, electroplating plants, etc.

It is spread by air and water (sewage sludge) far over sea and land, but especially in the vicinity of heavy industrial plants. Cadmium is today regarded as the most serious contaminant of the modern age. It is absorbed by many plants and seacreatures and, because of its toxicity, presents a major problem for foodstuffs. Contamination through fertilisers becomes an increasing problem.

Unlike lead, cadmium contamination cannot be removed from plants by washing them; it is distributed throughout the organism. It is often difficult to be certain of the cause of a cadmium content found in fruit or vegetables, as the substance in its natural form exists everywhere in the soil and is absorbed by the roots. For Central American cocoa, however, it has been possible to show that the increased cadmium content was related to the specific local constituency of the soil. As opposed to African cocoa kernels which contain 0.08-0.14 mg/kg, values from 0.18-1.5 mg/kg are found in the fine cocoa varieties from Venezuela and Ecuador, for example. The new sources from the Far East are also higher in cadmium content (see 4.2.4).

4.2.2 Toxic effects

Cadmium is concentrated particularly in the kidneys, the liver, the blood-forming organs and the lungs. It most frequently results in kidney damage (necrotic protein precipitation) and metabolic anomalies caused by enzyme inhibitions. It is now known that the ltai-itai sickness in Japan (with bone damage) is a result of the regular consumption of highly contaminated rice.

Cadmium, like lead, is a cumulative poison, i.e. the danger lies primarily in the regular consumption of foodstuffs with low contamination. However, in contrast to lead, the definition of an exact toxicity limit is not possible for cadmium. The decisive point is whether absorption of the existing cadmium actually takes place. This is, firstly, dependent upon the composition of the diet as a whole and, secondly, on the bio-availability of the cadmium compound present. No connection with cancerous disorders has been found.

4.2.3 Present contamination of foodstuffs and acceptable maximum values

Among the foodstuffs which present a problem are offal, crustaceans and shellfish and some fungi. Here, values of several mg/kg are found! Overall, however, vegetables are of greater importance for human cadmium contamination. Rice and wheat contain 10-150 μg/kg; meat, fish and fruit between 1 and 50 μg/kg. The Cd content of milk products is very low.

In most countries, there are legal regulations regarding permissible cadmium contamination levels. As a rule, these are based on the PTWI value last set by the JECFA of the FAO/WHO in 1989 of about 7 μg/kg body weight,

corresponding with a quantity of 0.4-0.5 mg per person (70 kg) per week.

The typical quantities of cadmium consumed per person per day in the western industrialised societies are between 10 and 50 μg, but these are considerably higher in some localities. 70 % of this comes from foodstuffs.

One problem of a special kind is the smoking of tobacco. 20 cigarettes a day provide a cadmium input of 4 μg!

4.2.4 The situation with regard to raw materials for confectionery

Only in the manufacture of plain chocolates with high proportions of fine cocoa could one come into a range where caution is demanded. Such chocolates are, in any way, not popular with children, which due to their low bodyweight exceed the PTWI more easily. No problems arise with other chocolates because sugar, milk powder, hazelnuts, etc. tend to have a diluting effect.

Theoretical calculation :

A child weighing 20 kg who, as an "intensive" consumer was theoretically assumed to eat 100 g of a chocolate with 10 % cocoa paste with 0.35 mg cadmium/kg every day, would have increased his weekly consumption of cadmium by 0.0012 mg per kg body weight. That is 16 % of the tolerable total quantity. If a cocoa paste with 1.83 mg/kg cadmium had been processed, the quantity consumed would have been 0.0063 mg/kg body weight. Even in this unlikely case, however, only 83 % of the weekly tolerable quantity of cadmium would have been consumed.

4.3 *Mercury*

4.3.1 The origin of mercury in foodstuffs and their surroundings

"Quicksilver" was already being extracted in ancient times. In 1972, world production from cinnabar was 9 000 t for industrial use in electrical engineering, for catalysts, thermometers and pigments, for pharmaceutical preparations (skin salves) and silver amalgam for filling teeth. It passes into the environment through emissions from chemical plants (paints, paper, chlorine, plant pesticides) and power stations, mostly in effluents and sludges. The situation in sea water is of particular significance. Mercury becomes concentrated in shellfish, crustaceans and fish and thus also passes, in the form of highly toxic mercury methylate, into the human food chain.

In 1965, the consumption of fish from regions of the sea contaminated by effluent led to the appearance of the so-called Minamata sickness in Japan and, in 1972, bread cereals contaminated with fungicides containing mercury led to epidemic poisoning in Iraq.

4.3.2 Toxic effects

Mercury in the form of its methyl compounds is specifically the most toxic of the heavy metals. When consumed orally, it first passes into the liver, the kidneys and the brain. Accumulation only takes place temporarily. A large part is excreted with the faeces. The salts of bivalent mercury, in the case of chronic consumption, first cause tiredness, loss of appetite and weight loss. In the end

the kidneys fail. Muscular weakness and paralysis are typical.

The methylmercury from animal foodstuffs also damages the central nervous system and the immune system. Teratogenic effects have also been observed.

4.3.3 Present contamination of foodstuffs and acceptable maximum values

Vegetable foodstuffs are only very slightly contaminated with mercury, except when they are grown in the vicinity of emitting industrial plants. Among animal foodstuffs it is practically only seafood which exhibits relatively high contents of mercury. A special case are animals which are fattened on contaminated fishmeal.

The FAO/WHO Expert Committee (JECFA) has set a provisional maximum acceptable value for mercury consumption at 5 μg per kg body weight per week. Of this, however, not more than 55 % may be present in the form of organically bonded mercury (so-called methylmercury). For a person weighing 70 kg this represents a quantity of 0.35 mg total Hg per week (of which not more than 0.19 mg may be organically bonded). The average consumption of mercury varies in uncontaminated parts of the world between 20 and 80 μg per day, but in contaminated regions is often temporarily higher. At these consumptions, however, the PTWI values quoted above are only reached in exceptional cases. Up to 80 % of the quantities of mercury consumed, originate by way of the food chain, either directly or indirectly from seafood.

4.3.4 The situation with regard to raw materials for confectionery

Practically no mercury contamination problem exists for confectionery and fine bakery wares.

4.4 *Other heavy metals*

Some heavy metals (the so-called trace elements) are essential in very small concentrations for the survival of all life forms, for example, copper, iron, zinc, chromium, molybdenum and others. It is possible that not all are yet known.

Despite this fact, it is often forgotten that in some circumstances, in higher concentrations, these can also be quite toxic, for example when they are present in an organic compound.

Nickel has often been associated recently with allergies (contact with jewellery and jeans buttons containing nickel). There is no established knowledge of effects of this type when it is absorbed in the gastro-intestinal tract. Cocoa is one of the foodstuffs with higher than average natural nickel contents.

The copper content of tomato dishes prepared in copper pots and having a copper content of 0.1-0.2 mg/kg body weight has already been found to cause digestive disturbances in sensitive consumers! This is in spite of the specified tolerable quantity for daily consumption of 0.5 mg/kg.

Chromium, copper and zinc play major roles in modern industry and, in the vicinity of extraction or processing plants, the emissions arising are certainly capable of causing an undesirable contamination of agricultural products. Considerable quantities have been found in fruit and vegetables. However, no adverse effects on health are known. It is nevertheless recommended not to omit these metals a priori from scrutiny.

5. Worldwide report and control system GEMS

The members of the United Nations have long been called upon to take part in the "Global Environment Monitoring System GEMS". In 1991 it was announced that, of 21 countries whose institutes had reported, there was only one case in which the PTWI value for cadmium was exceeded. In general, cereal products and tuber and root vegetables are said to be most severely contaminated with cadmium.

Whether seafood is really the main source of mercury in foodstuffs has also already been questioned. The consumption quantities for lead reach or exceed the PTWI values of the FAO/WHO in many countries.

6. The IOCCC position

The total avoidance of the consumption of heavy metals through foodstuffs, including confectionery, is not possible because these are often already naturally present in many raw materials.

There are no acute problems for the confectionery industry arising from the heavy metal contents of raw materials as long as the composition of the articles remains true to type. In the case of fine cocoa and some fruit concentrates, caution should be observed.

BIBLIOGRAPHY

1. ABDULLA, M., J. CHMIELNICKA: New Aspects on the Distribution and Metabolism of Essential Trace Elements after Dietary Exposure to Toxic Metals. Biological Trace Element Research **23** 25-53 (1990)

2. ANDREY, D., H. BEUGGERT, M. CESCHI, G. CORVI, M. DE ROSSA, A. HERRMANN, B. KLEIN, N. PROBST-HENSCH: Monitoring Programm "Schwermetalle in Lebensmitteln". IV. Blei, Cadmium, Kupfer und Zink in Weinen auf dem Schweizer Markt, Teil B: Vorgehen, Resultate und Diskussion (1). Mitt. Gebiete Lebensm. Hyg. **83** 711-736 (1992)

3. BECKER, W., J. KUMPLAINEN: Contents of essential and toxic mineral Elements in Swedish Market-Baskets diets in 1987. British Journal of Nutrition **66** 151-160 (1991)

4. BOSSHARD, **E.,** B. ZIMMERLI: Bedarfsgegenstände aus Kupfer und Kupferlegierungen, ein Gesundheitsproblem? Mitt. Gebiete Lebensm. Hyg. **85** 287-311 (1994)

5. BULINSKI, R., **J.** BLONIARZ, B. LIBELT: Presence of some Trace Elements in Polish Food Products. XV. Contents of Lead, Copper, Cadmium, Nickel, Chromium, Zinc, Cobalt, Manganese, Copper and Iron in some Milk Products. Bromatologia i. Chemia Toks, **26** 23-27 (1993)

6. CHANG, L. W.: The Neurotoxicology and Pathology of Organomercury, Organolead and Organotin. Biomed. Environ Sci. Res. **3** 125-151 (1990)

7. CODEX ALIMENTARIUS COMMISSION: CX/FAC 95/18. Nov. 1994. Discussion Paper on Lead. 22. Sess. March 1995

8. CODEX ALIMENTARIUS COMMISSION: CX/FAC 95/19. Nov. 1994. Position Paper on Cadmium. 27. Sess. March 1995

9. DARMONO, D., G. R. W. DENTON: Heavy Metall Concentrations in the Banana prawn, Peneaus merguiensis, and leader prawn, P. monodon, in the townsville region of Australia. Bull. Environ. Contam, Toxicol. **44** 479-486 (1990)

10. ELMADFA, I., J. KÖNIG: Quecksilber. Verbraucherdienst **35** 8-14 (1990)

11. EWERS, U.: Toxikologische Beurteilung der Schwermetallautnahme, Off. Gesundh.-Wes. **52** 381-386 (1990)

12. GALAS-GORCHEV, H.: Dietary Intake of Pesticide Residues: Cadmium, Mercury and Lead. Food Add. and Cont. **8** 793-806 (1991)

13. GAZZA, F.: Lead and Cadmium: Sources, Metabolism, Dangers and Presence in Meat and Meat Products. Ann. della Facolta di Med.Vet. **10** 171-181 (1990)

14. GROTEN, J. P., E. J. SINKELDAM, J. B. LUTEN, P. J. VAN BLADEREN: Comparison of the Toxicity of inorganic and liver-incorporated Cadmium: A 4-week Feeding study in Rats, Food and Chem. Tox. **28** 435-441 (1990)

15. GROTEN, J. P., P. **J.** VAN BLADEREN: Cadmium Bioavailability and Health Risk in Food. Trends in Food Science & Technology **5** 50-55 (1994)

16. HENICK-KLING, T., G. S. STOEWSAND: Lead in Wine. American Journal of

Enology and Viticulture **44** 459-463 (1993)

17. IGWEGBE, A. 0., H. M. BELHAJ, T. M, HASSAN, A. S. GIBALI: Effect of Highway's Traffic on the Level of Lead and Cadmium in Fruits and Vegetables grown along the roadsides. Journal of Food Safety **13** 7-18 (1992)

18. JECFA: 33. Report: Evaluation of certain food additives and contaminants, WHO Techn. Report Series 776. Genf 1989

19. JECFA: 33. Report: Evaluation of certain food additives and contaminants, WHO Techn, Report Series 837. Genf 1993

20. JONES, R. R.: The Continuing Hazard of Lead in Drinking Water. Lancet 16 669-670 (1989)

21. KAUFMANN, A.: Messing, eine mögliche Ursache für erhöhte Bleikonzentrationen in Wein. Mitt. Gebiete Lebensm. Hyg. **83** 204-210 (1992)

22. KNEZEVIC, G.: Keine Belastung durch Spurenelemente. Zucker- und Süßwarenwirtschaft 40 287-289 (1987)

23. LEUBOLT, R., A. URBAN, M. BERCHTOLD, M. PETER, J. PUESPOEK: Schwermetalle im Brauprozess. I. Brauereirohstoffe und Osterreichische Biere. Mittelösterreichische Getränke-Industrie **45** 133-139 (1991)

24. MASLOWSKA, J., M. AHMADI: Determination of presence of toxic elements in Molasses and defeco-saturation sludge by atomic emission Spectr. Przemysl Spozywczy **45** 201-203 (1991)

25. MATISSEK, R,, H. G. BURKHARDT: Schwermetallspuren in Kakao und Kakaoerzeugnissen. Gordian **89** 157-162 (1989)

26. N.N.: Richtwerte für Blei, Cadmiurn und Quecksilber in und auf Lebensmittein. BGesundhBI, **29** (1986)

27. N.N.: Schadstoffe in Lebensmitteln - ein Risiko? Fortschr, Med. **108** 13 (1990)

28. OSKARSSON, A.: Health Aspects of Methylmercury in Fish. Var Foeda **44** 148-154 (1992)

29. OSKARSSON, A.: Health Hazard of high concentrations of Copper in Drinking Water. Var Foeda **41** 257-259 (1989)

30. PALMER, S., G. MOY., Environmental Pollution, Food Contamination and Public Health. European Journal of Clinical Nutrition **45** 144-146 (1991)

31. RUICK, G.: Ergebnisse eines Monitoring-Programmes zur Ermittlung der Aufnahme von Kupfer, Blei, Cadmium, Zink und Nickel in Lebensmitteln. Z.Lebensm.Unters.Forsch. **192** 249-251 (1991)

32. SCHUMACHER, M., J. L. DOMINGO, J. M. LLOBET, J. CORBELLA: Chromium, Copper and Zinc Concentrations in Edible Vegetables Grown in Tarragona Province, Spain. Bull.
Environ. Contam. Toxicol. **50** 514-521 (1993)

33. SCHÜMANN, K.: Zur toxikologischen Beurteilung der Schwermetallgehalte (Cd, Hg, Pb) in Säuglings- und Kleinkindnahrung. Z Ernährungswiss **29** 54-73 (1990)

34. SILVA, A., V. MAZZOLENI, 0. COLAGRANDE: Lead contents of Wine and possible Sources of Contamination. ind. delle Bevande **22** 211-216 (1993)

35. TEISSEDRE, P. L., M. T. CABANIS, F. CHAMPAGNOL, I. C. CABANIS: Lead Distribution in grape berries, American Journal of Enolgogy and Viviculture **45** 220-228 (1994)

36. THIMOTHY, P., D. M. LATTA, E, T, SNOW, M. COSTA: Toxicology and Carcinogenicity of Nickel Compounds. Crit, Rev. in Toxicology **19** 341-383 (1989)

37. VAN DOKKUM, W., H. DE VOS, TH. MUYS, J. A. WASSTRA: Minerals and Trace Elements in Total Diets in the Netherlands. British Journal of Nutrition **61** 7-15 (1989)