

**Partial Agreement
in the Social and Public Health Field
Accord Partiel
dans le domaine social et de la santé publique**



**COUNCIL OF EUROPE'S POLICY STATEMENTS
CONCERNING MATERIALS AND ARTICLES
INTENDED TO COME INTO CONTACT WITH FOODSTUFFS**

**POLICY STATEMENT
CONCERNING METALS AND ALLOYS**

**TECHNICAL DOCUMENT
GUIDELINES ON METALS AND ALLOYS
USED AS FOOD CONTACT MATERIALS**

(13.02.2002)

TECHNICAL DOCUMENT

**GUIDELINES ON METALS AND ALLOYS
USED AS FOOD CONTACT MATERIALS**

NOTE TO THE READER

The Guidelines on metals and alloys used as food contact materials are part of the Council of Europe's policy statements concerning materials and articles intended to come into contact with foodstuffs.

The present document may be consulted on the Internet website of the Partial Agreement Department in the Social and Public Health Field:

www.coe.fr/soc-sp

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PART I

COUNCIL OF EUROPE AND FOOD CONTACT MATERIALS

1. Council of Europe

The Council of Europe is a political organisation which was founded on 5 May 1949 by ten European countries in order to promote greater unity between its members. It now numbers 43 member States¹.

The main aims of the Organisation are to reinforce democracy, human rights and the rule of law and to develop common responses to political, social, cultural and legal challenges in its member States. Since 1989 the Council of Europe has integrated most of the countries of Central and Eastern Europe into its structures and supported them in their efforts to implement and consolidate their political, legal and administrative reforms.

The work of the Council of Europe has led, to date, to the adoption of over 170 European conventions and agreements, which create the basis for a common legal space in Europe. They include the European Convention on Human Rights (1950), the European Cultural Convention (1954), the European Social Charter (1961), the European Convention on the Prevention of Torture (1987) and the Convention on Human Rights and Bioethics (1997). Numerous recommendations and resolutions of the Committee of Ministers propose policy guidelines for national governments.

The Council of Europe has its permanent headquarters in Strasbourg (France). By statute, it has two constituent organs: the Committee of Ministers, composed of the Ministers of Foreign Affairs of the 43 member States, and the Parliamentary Assembly, comprising delegations from the 43 national parliaments. The Congress of Local and Regional Authorities of Europe represents the entities of local and regional self-government within the member States. A multinational European Secretariat serves these bodies and the intergovernmental committees.

2. The Partial Agreement in the social and public health field

Where a lesser number of member states of the Council of Europe wish to engage in some action in which not all their European partners desire to join, they can conclude a 'Partial Agreement' which is binding on themselves alone.

The Partial Agreement in the social and public health field was concluded on this basis in 1959.

The areas of activity of the Partial Agreement in the social and public health field include two sectors:

- Protection of public health
- Rehabilitation and integration of people with disabilities.

¹ Albania, Andorra, Armenia, Austria, Azerbaijan, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, The Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, San Marino, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, "the former Yugoslav Republic of Macedonia", Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland.

At present, the Partial Agreement in the public health field has 18 member states¹.

The activities are entrusted to committees of experts, which are responsible to a steering committee for each area.

The work of the Partial Agreement committees occasionally results in the elaboration of conventions or agreements. The more usual outcome is the drawing-up of resolutions of member states, adopted by the Committee of Ministers. The resolutions should be considered as statements of policy for national policy-makers. Governments have actively participated in their formulation. The delegates to the Partial Agreement committees are both experts in the field in question and responsible for the implementation of government policy in their national ministries.

The procedure provides for considerable flexibility in that any state may reserve its position on a given point without thereby preventing the others from going ahead with what they consider appropriate. Another advantage is that the resolutions are readily susceptible to amendment should the need arise. Governments are furthermore called upon periodically to report on the implementation of the recommended measures.

A less formal procedure is the elaboration of technical documents intended to serve as models for member states and industry.

Bodies of the Partial Agreement in the social and public health field enjoy close co-operation with equivalent bodies in other international institutions, in particular the Commission of the European Union. Contact is also maintained with international non-governmental organisations (NGOs) and industry, working in similar or related fields.

3. Council of Europe committees in the public health field

- Public Health Committee (Steering Committee)
- Committee of experts on materials coming into contact with food

Ad hoc Groups of the Committee of experts:

- Ad hoc Group on safety evaluation
- Ad hoc Group on recycled fibres (with industry participation)
- Ad hoc Group on test conditions for paper and board (with industry participation)
- Ad hoc Group on tissue papers (with industry participation)
- Ad hoc Group on packaging inks (with industry participation)
- Ad hoc Group on coatings (with industry participation)
- Ad hoc Group on cork (with industry participation)
- Ad hoc Group on rubber (with industry participation)

- Committee of experts on nutrition, food safety and consumer health

Ad hoc Groups of the Committee of experts:

- Ad hoc Group on functional food (with industry participation)
- Ad hoc Group on nutrition in hospitals
- Ad hoc Group on stored product protection

¹ Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, The Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland.

- Committee of experts on flavouring substances
 - Ad hoc Group of the Committee of experts:
 - Ad hoc Group on active principles
- Committee of experts on cosmetic products
 - Ad hoc Group of the Committee of experts:
 - Ad hoc Group on active ingredients
- Committee of experts on pharmaceutical questions
- Committee of experts on medicines subject to prescription

4. Terms of reference of the Committee of experts on materials coming into contact with food

The overall aim of the Council of Europe Partial Agreement public health activities is to raise the level of health protection of consumers and food safety in its widest sense.

The terms of reference of the Committee of experts on materials coming into contact with food (hereafter called 'Committee of experts') are part of the overall aim of these activities and are related to precise problems concerning food contact materials and articles.

The representatives of the Partial Agreement member states and delegates of the Committee of experts are both experts in the field of food contact materials and responsible for the implementation of government policies in their national ministries.

The Commission of the European Union has a particular status of participation within the Committee of Experts.

European industry branch associations are not entitled to send representatives to the meetings of the Committee of experts. They may be represented at the level of the Ad hoc Groups, which are advisory bodies to the Committee of experts. Ad hoc Groups are not entitled to take formal decisions.

Hearings are regularly organised between the Committee of experts and the European industry branch associations on specific questions related to the work programme.

5. Main tasks of the Committee of experts on materials coming into contact with food

▪ Elaboration of resolutions

Resolutions elaborated by the Committee of experts are approved by the Public Health Committee and adopted by the Committee of Ministers¹;

They have to be considered as statements of policy or statements for national policy-makers of the Partial Agreement member states to be taken into account in the national laws and regulations on materials and articles intended to come into contact with foodstuffs, with the view of harmonising regulations at European level.

They lay down the field of application, the specifications and the restrictions concerning the manufacture of materials and articles intended to come into contact with foodstuffs.

If necessary, they are amended in order to update their content.

▪ Elaboration of technical documents

Technical documents elaborated by the Committee of experts and/or Ad hoc Groups, are approved by the Committee of experts and adopted by the Public Health Committee. They are not submitted to the Committee of Ministers.

They have to be considered as models and requirements to be taken into account in the context of resolutions or as models and requirements alone for the implementation of national policies.

They provide practical guidance for the application of resolutions and/or lay down technical and/or scientific specifications for the manufacture of materials and articles intended to come into contact with foodstuffs.

If necessary, they are amended in the light of technical and/or scientific developments of manufacturing processes and techniques of materials intended to come into contact with foodstuffs.

Typical examples of technical documents are:

List of substances for the manufacture of materials and articles intended to come into contact with foodstuffs

Guidelines concerning the manufacture of materials and articles intended to come into contact with foodstuffs

¹ The Committee of Ministers is the Council of Europe's political decision-making body. It comprises the Ministers for Foreign Affairs of the forty-three member states, or their permanent diplomatic representatives in Strasbourg. It monitors member states' compliance with their undertakings. Resolutions of the Partial Agreement in the social and public health field are adopted by the Committee of Ministers restricted to Representatives of the member states of the Partial Agreement.

Good manufacturing practices (GMP) concerning the manufacture of materials and articles intended to come into contact with foodstuffs

Test conditions and methods of analysis for the manufacture of materials and articles intended to come into contact with foodstuffs

Practical guides for users of resolutions and technical documents

- **Elaboration of opinions**

On request by the Committee of Ministers and/or the Public Health Committee, the Committee of experts elaborates opinions on specific questions related to food contact materials and articles which are submitted for adoption to its superior bodies.

PART II

GUIDELINES ON METALS AND ALLOYS USED AS FOOD CONTACT MATERIALS

1. Introduction

Metals and alloys are used as food contact materials, mainly in processing equipment, containers and household utensils but also in foils for wrapping foodstuffs. They play a role as a safety barrier between the food and the exterior. They are often covered by a surface coating, which reduces the migration in foodstuffs. When they are not covered these food contact materials can give rise to migration of metal ions into the foodstuffs and therefore could either endanger human health if the total content of the metals exceeds the sanitary recommended exposure limits, if any, or bring about an unacceptable change in the composition of the foodstuffs or a deterioration in their organoleptic characteristics. Therefore it was deemed necessary to establish these guidelines to regulate this sector.

These Guidelines do not deal with the following issues:

- Exposure through inhalation, skin contact etc. The guidelines only cover the oral intake of metallic elements. Inhalation, skin contact etc. is not covered by the guidelines even though there may be toxicological implications connected to these exposures
- Nutritional aspects, as the guidelines deal with the elements from the migration point of view and thus consider the elements as being contaminants, even though some of them are essential elements.

1.1. Co-operation with industry

These Guidelines have been elaborated by the Council of Europe Committee of experts on materials coming into contact with food, after consultation of the representatives of the following professional associations:

APEAL (The Association of European Producers of Steel for Packaging),
BCCCA (The Biscuit, Cake, Chocolate & Confectionery Alliance),
EUROFER (European Confederation of Iron and Steel Industries),
EUROMETAUX (European Association of the Non Ferrous Metals Industry),
EIMAC (European Industry Metals and Alloys Classification Group), and
SEFEL (European Metal Packaging Manufacturers Association (Société Européenne de Fabricants d'Emballage Métallique léger).

2. Legal status of the Guidelines and their update

These Guidelines are not legally binding but are considered by the member states represented in the Council of Europe Committee of experts on food contact materials as a reference document to assist enforcement authorities, industry and users to ensure

compliance of metals and alloys used for food contact materials with the provisions of Article 2.2 of Directive 89/109/EEC. Guidelines are considered as a less formal procedure than resolutions. They are 'Technical documents' which are approved by the Committee of experts. These Guidelines will be updated by the Committee of experts in the light of technical and/or scientific developments.

3. Field of application

These Guidelines apply to any type of materials and articles, manufactured or imported in Europe, intended to come into contact with foodstuffs made completely or partly of metals and alloys ("metallic materials"), i.e. household utensils and processing equipment like food processors, transportation bands, wrapping, containers, pots, stirring pots, knives, forks, spoons etc.

3.1. Definition of metals and alloys

Metals are usually characterised on the basis of their chemical and physical properties in the solid state. Metals are the class of materials linked on an atomic scale by the metallic bond. The metallic bond may be described as an array of positive metallic ions forming long-range crystal lattices in which valency electrons are shared commonly throughout the structure. Such structures give rise to the following properties typical of the metallic state (Vouk, 1986):

- High reflectivity which is responsible for the characteristic metallic lustre
- High electrical conductivity which decreases with increasing temperature
- High thermal conductivity
- Mechanical properties such as strength and ductility

Metallic alloys are composed of two or more metallic elements. A more specific definition of alloys is given in the separate guideline on alloys.

3.2. Metals and alloys covered by the Guidelines

The following metallic materials are covered by these Guidelines:

- Aluminium
- Chromium
- Copper
- Iron
- Lead
- Manganese
- Nickel
- Silver
- Tin
- Titanium
- Zinc
- Stainless
- Other alloys

The Guidelines also cover::

- Cadmium
- Cobalt
- Mercury

because these metals are present as impurities or contaminant in some metallic materials and, therefore, they can migrate in foodstuffs (see Appendix 1).

Furthermore, antimony, arsenic, barium, molybdenum, thallium, and magnesium could be addressed in Appendix I at a later stage.

A guideline for beryllium has been considered. However, as beryllium was found only to be used in copper beryllium alloys in metal mould tools for making plastic containers and as no transfer of beryllium to the plastic has been found it was considered unnecessary to establish a guideline for beryllium.

3.3. Metals and alloys not covered by the Guidelines

These Guidelines do not cover the following materials which may contribute to the intake of metals:

- Ceramics, crystal glass, printing inks, lacquers, aids for polymerisation and other types of materials, which are either covered by specific legislation in the EU or by Council of Europe resolutions. However, if metals are migrating from these materials into foodstuffs this contribution should also be considered in the overall evaluation of the metal content of the final foodstuffs and the total exposure.
- Any special requirements for pipelines for drinking water as drinking water is of special concern and is covered by separate international legislation. Furthermore, drinking water is not classified as a foodstuff in all member states.
- Those metallic materials which are covered by a layer of surface coatings able to constitute a “functional barrier” to the migration of the metals into the foodstuffs thereby reducing the potential risk of migration of the metal.
- Toys. Even though toys are often found in breakfast cereals etc. in direct food contact, the guidelines do not cover migration from toys.
- Active packaging or other active food contact articles. Active packaging is here defined as a food contact material or article, which does more than simply provide a barrier to outside influence. It can control, and even react to, events taking place inside the package. Some articles for food contact are used with an intended migration of the metals into the foodstuff.

The migration is intended due to some effects of the metals in the foodstuffs. This is the case for copper in cheese-making and for tin in some canned foodstuffs. The use of metals with an intentional migration corresponds to the use of food additives or active packaging.

These materials all contribute to the intake of metals and their contribution to the total oral intake should be taken into account in the health evaluation (see also § 4.4). However, these guidelines only cover materials and articles made exclusively of metals and alloys.

4. General requirements and recommendations

4.1. Health aspects

In compliance with Article 2 of Directive 89/109/CEE metallic materials under normal and foreseeable conditions, should meet the following conditions:

They should be manufactured in accordance with good manufacturing practice and they should not transfer their constituents to foodstuffs in quantities, which could:

- endanger human health
- bring about unacceptable change in the composition of the foodstuffs or a deterioration in the organoleptic characteristics thereof.

It must be stressed that the release of a substance through migration should be reduced as low as reasonably achievable not only for health reasons but also to maintain the integrity of the foodstuffs in contact.

Where specific migration limits have been, or can be set, these limits should be fulfilled taking into account also the contribution of the natural presence of metals in foodstuffs. Where specific migration limits have not been set the levels of migration into foodstuffs should be assessed in relation to health evaluations carried out by recognised scientific bodies where available, and in particular take account of dietary exposure including the natural presence of metals in foodstuffs (see also § 4.4).

Where necessary manufacturers of metals and alloys which are used in contact with foodstuffs should provide guidance on aspects of manufacture, e.g. compositional limits, or aspects of use, which affect chemical migration. In particular the temperature and storage time is known to influence the migration of constituents of packaging materials into certain types of foodstuff. Producers should label products with guidance to use. The labelling could include for instance restricted use for storage of strongly acidic or salty foodstuffs. The labelling could also include guidance on temperature storage of wet food in order to minimise migration. The labelling could be "Should be kept below 5 °C if the food will remain packaged for longer than 24 hours". These labelling requirements would not be relevant for canned food.

Remark: It should be recognised that industrial use and household use of materials for food contact might vary greatly. Industrial environment normally implies process control, repeated use of the same equipment according to standard conditions, selection and qualification of the food contact material (equipment or packaging) for a given foodstuff and use, possible liability of the manufacturer in case of damage to consumers. Household use normally implies a wide range of foodstuffs and contact conditions, uncontrolled use of utensils limited only by concepts such as "current practice" or reasonably foreseeable use conditions. Therefore, labelling with guidance of use from the producer to the consumer could limit inappropriate use of the food contact materials.

4.2. Hygienic aspects

Materials for food contact should comply with chapter V in the annex of Directive 93/43/EEC on the hygiene of foodstuffs. Chapter V concerns equipment requirements and states the following:

"All articles, fittings and equipment with which food comes into contact shall be kept clean and:

- (a) be so constructed, be of such materials and be kept in such good order, repair and condition as to minimize any risk of contamination of the food;
- (b) With the exception of non-returnable containers and packaging, be so constructed, be of such materials and be kept in such good order, repair and condition as to enable them to be kept thoroughly cleaned and, where necessary, disinfected, sufficient for the purposes intended;
- (c) be installed in such a manner as to allow adequate cleaning of the surrounding area."

4.3. Migration testing aspects

In order to enforce the principle of inertness, the level of migration of the metals into the foodstuffs should be determined in the worst foreseeable conditions, taking into account the natural content in the metal of the foodstuffs itself. Only this evaluation can be used in order to establish the compliance with these guidelines.

However, in order to evaluate the maximum potential release of the metals, in principle, the migration testing described in the Appendix of the Directive 97/48/EC is recommended with the exception of acidic foodstuffs. In fact, for acidic foodstuffs, pending the selection of an appropriate test medium¹, the test in foodstuffs itself should be carried out otherwise the phenomenon of corrosion may be produced .

The use of validated or the generally recognised reference method is recommended for the determination of the content of the metals in foodstuffs or in food simulants. However, the preparation of these methods is outside the scope of these guidelines.

4.4. Health evaluation aspects

The health evaluations mentioned in these Guidelines are related only to oral exposure and therefore they do not take into consideration other routes of exposure (inhalation, dermal etc.). It is important to notice that the bioavailability and toxicity of a metal may depend on the metal compound or ionic species present (Florence and Batley, 1980). Usually, the knowledge on speciation in relation to migration and the toxicity of the individual relevant metal compounds is limited. Chemical speciation may be defined as the determination of the individual concentrations of the various chemical forms of an element which together make up the total concentration of that element in a sample (Florence and Batley, 1980). In the case of metal toxicity, it is in most cases accepted that the free (hydrated) metal ion is the most toxic form, whereas strongly complexed bound metal is much less toxic (Florence and Batley, 1980). However, an exception to this is mercury.

Any risk assessment of a substance which can endanger human health, e.g. metals, should cover exposure from all sources through oral uptake, including migration from food contact materials and, if available, other sources of food contamination. Also the natural content of metals in the foodstuffs should be considered (see Table in Appendix III).

¹ A research is ongoing in the Nehring Institute to select a test medium more appropriate than the acetic acid 3% used in the past. Further research in the field of the selection of more appropriate test media are recommended.

In principle, the maximum quantity of metals which can be absorbed by man from all sources should not exceed daily or weekly the TDI's and the PTWI's (multiplied by a body weight of 60 kg) established by JECFA or the Scientific Committee for Food of the EU (SCF) or by other international bodies. In Appendix II the existing JECFA PTWI's and TDI's have been listed.

However, it should be stressed that the exceeding of these above-mentioned sanitary limit values should be considered as non-compliant action (i.e. action not in compliance with the principle of inertness) and not necessarily as an action to endanger human health. In fact, to determine whether the PTWI or TDI is exceeded it is advisable to consider contribution of the metal in foodstuffs and the dietary habits, together with the level of migration. Moreover, it should be reminded that JECFA has stated that "short-term exposure to levels exceeding the PTWI is not a cause for concern, provided the individual's intake averaged over longer periods of time does not exceed the level set".

If there is a lack of international sanitary limit values, it is recommended to apply the method currently used by international bodies in the risk assessment.

4.5. Other related aspects

The technical specifications for metallic materials set out in the European Standard EN ISO 8442-1 should be also taken into account.

It would be too overwhelming to mention all related work being carried out concerning either migration, migration testing or toxicological evaluations of metals or alloys. However, the work on evaluation and control of risks of existing substances should be mentioned. This work is based in the EU Council Regulation 793/93/EEC of March 23, 1993 (L84 p. 1-75) and involves nickel, chrome and zinc among others.

4.5.1. Corrosion

Corrosion is a phenomenon in which, in the presence of moisture and oxygen, the metal undergoes an electrochemical reaction with components of the surrounding medium. In the simple case of uniform corrosion, this reaction results in the formation of compounds of the metal (e.g. hydroxides) on the surface of the metal. The rate at which corrosion proceeds will depend in part on the composition of the aqueous medium: corrosion of iron in very pure water will be considerably slower than in water which contains, for example, acids or salts. The rate of corrosion depends also on the solubility of the formed compounds in the medium, and their rate of removal. Thus, for example, formed compounds may be removed rapidly in a flowing aqueous medium, and the corrosion rate will be high. In a static medium, the rate of corrosion will be moderated as the ionic concentration of the surrounding medium increases. Corrosion products formed in the atmosphere are more or less adherent e.g. rust on iron, verdigris on copper. Rust is essentially hydrated ferric oxide which usually also contains some ferrous oxide and may contain iron carbonates and/or sulfates. Similarly, verdigris consists mainly of basic copper carbonate, but may also contain copper sulfates and chlorides. However, rust is loose and easily removed, while verdigris forms a stable patina.

More complex corrosion patterns may occur e.g. "pitting corrosion". This occurs following attack at discrete areas on the surface of the metal that are susceptible because of, for example, surface imperfections or impurities in the metal. Pitting corrosion is generally seen as small, local, areas of corrosion. However, there may be considerably larger areas of corrosion beneath the surface that can have significant effects on the strength of the affected metal.

4.5.2. Corrosion resistance

Some metals (e.g. aluminium, chromium) are rendered "passive" (very resistant to corrosion) by the spontaneous formation, in the presence of oxygen, of an invisible and impermeable oxide film a few Å thick. This passive layer is very strong, very adherent and self-repairing if it is damaged.

One of the main reasons for the production and use of metallic alloys is that alloys are virtually always more resistant to corrosion than are their basic metal components.

This is due, in part, to the fact that migration of the constituent elements is generally considerably lower than migration from non-alloyed metals because of the micro-structural binding of the elements within the alloys. The relevant properties of alloys are described in more detail in the specific section on alloys, below.

Stainless steels, which are alloys of iron with a minimum of 10.5% chromium, are orders of magnitude more resistant to corrosion than iron itself. This is partly because they possess the general properties of alloys, referred to above, but mainly because they have a surface "passive film" which is naturally and rapidly formed on contact with the oxygen in air or water. Stainless steels used in food contact applications are invariably used in the passive state. The corrosion resistance of stainless steels is discussed in more detail in the specific section on stainless steels.

4.6. Abbreviations used

ADI	Acceptable Daily Intake.
FAO	Food and Agricultural Organization in UN.
JECFA	Joint FAO/WHO Expert Committee on Food Additives
NOAEL	No Observed Adverse Effect Level.
PMTDI	Provisionally Maximum Tolerable Daily Intake.
PTWI	Provisionally Tolerable Weekly Intake.
SCF	Scientific Committee on Food of the European Union.
TDI	Tolerable Daily Intake.
WHO	World Health Organization in UN.

4.7. References

Directive 89/109/EEC: European Community. Council directive on the approximation of the laws of the member states relating to materials and articles intended to come into contact with foodstuffs. L40, p. 38.

Directive 93/43/EEC: Council directive on the hygiene of foodstuffs. L 175 p. 1-11.

Directive 97/48/EEC: European community. Council directive on control of migration from plastic articles. L 222 p. 10.

EN ISO 8442-1. European Standard. Materials and articles in contact with foodstuffs - cutlery and table hollow-ware - Part 1: Requirements for cutlery for the preparation of food (ISO/DIS 8442-1:1997). Final draft, May 1997.

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SPECIFIC GUIDELINES

Guideline for aluminium

Introduction

Aluminium is the third most abundant element in the earth crust and is found widespread in minerals (Codex, 1995). Aluminium does not occur in nature in a free element state because of its reactive nature (Beliles, 1994). Many of its natural-occurring compounds are insoluble at neutral pH and thus concentrations of the element in water, both fresh and sea-water are usually low, less than 0.1 mg/l. Inorganic compounds of aluminium normally contain Al(III). Pure aluminium has good working and forming properties and high ductility, its mechanical strength being low. Therefore, aluminium is often used in alloys (Beliles, 1994).

Main sources of aluminium in the diet

The main source of aluminium is the natural occurring content in foodstuff. Unprocessed foodstuff can contain between about 0.1 to 20 mg/kg of aluminium. The measured levels of aluminium in unprocessed foodstuffs range from less than 0.1 mg/kg in eggs, apples, raw cabbage, corn, and cucumbers (ATSDR, 1997) to 4.5 mg/kg in tea (Pennington and Jones, 1989; Pennington and Schoen, 1995; MAFF, 1993); much higher values are found in some industrially processed food with aluminium salts added as food additives. However, in the EU the use of aluminium salts as food additives is limited to certain products like scones and aluminium itself is accepted for decoration of confectionary (Directive 95/2/EC). Aluminium is also used in medical therapy in amounts up to 5 g/person/day (Codex, 1995; Elinder & Sjögren, 1986; Lione, 1985).

Metallic food contact materials

Aluminium is widely used in food contact materials such as saucepans, aluminium-lined cooking utensils, coffee pots, and in packaging products such as food-trays, cans, can ends and closures (Elinder and Sjögren, 1986; Codex, 1995). Aluminium food contact materials are often coated with a resin based coating. Aluminium alloys for food contact materials may contain alloying elements such as magnesium, silicone, iron, manganese, copper and zinc (European Standard EN 601; European Standard EN 602).

Other food contact materials

Certain aluminium compounds are used in pigments (Elinder and Sjögren, 1986).

Migration information

Aluminium and its various alloys are highly resistant to corrosion (Beliles, 1994). When exposed to air, the metal develops a thin film of Al_2O_3 almost immediately. The reaction then slows because the film seals off oxygen, preventing further oxidation or chemical reaction. The film is colourless, tough and nonflaking. Few chemicals can dissolve it (Beliles, 1994).

Aluminium reacts with acids. Pure aluminium is attacked by most dilute mineral acids. At neutral pH, aluminium hydroxide has limited solubility. However, the solubility increases markedly at pH below 4.5 and above 8.5 (Elinder and Sjögren, 1986). Alkalis attack both pure and impure aluminium rapidly and dissolve the metal (Hughes, 1992). Therefore, aluminium can migrate from uncoated surfaces in contact with foodstuff. Aluminium migration from coated aluminium surface is insignificant. Uptake of aluminium from uncoated food contact materials depends to a large extent on the acidity of the foodstuffs. High salt concentrations (over 3.5% NaCl) can also increase the migration. Use of uncoated aluminium saucepans, aluminium-lined cooking utensils and containers may increase the content of aluminium in certain types of foodstuffs, especially during long-term storage of strongly acidic or salty, liquid foodstuff. In general, cooking in aluminium vessels increases the content in the foodstuffs less than 1 mg/kg for about half the foodstuffs examined, and less than 10 mg/kg for 85% of the foodstuffs examined (Pennington and Jones, 1989). Boiling of tap water in an aluminium pan for 10 or 15 minutes can result in aluminium migration of up to 1,5 mg/l, depending on the acidity of the water and the chemical composition of the aluminium utensils (Gramiccioni et al., 1996; Müller et al., 1993; Mei et al., 1993; Nagy et al., 1994) but values up to 5 mg/l have been reported in one study (Liukkonen-Lilja and Piepponen, 1992). The foodstuffs which most frequently take up more aluminium from the containers are acidic foodstuffs such as tomatoes, cabbage, rhubarb and many soft fruits (Hughes, 1992). Whilst acids give the highest figures, alkaline foodstuffs (less common) and foodstuffs with much added salt, do increase the aluminium uptake (Hughes, 1992; Gramiccioni et al., 1996). In aluminium cans the production of hydrogen gas from aluminium migration produces an over pressure in the can.

The temperature and storage time is known to influence the migration of aluminium into foodstuff. In a migration study with 3% acetic acid (Gramiccioni et al., 1989), the migration was approximately 10 fold higher at 40°C compared to 5°C after 24 hours (for general remarks on migration testing – see the introduction). Typical values for migration of aluminium from foil was <0.05 mg/dm² at 5°C and correspondingly 6 mg/dm² at 40°C. However, after 10 days, the migration was considerably higher: 0.5 mg/dm² at 5°C compared to 96 mg/dm² at 40°C (Gramiccioni et al., 1989).

Safety aspects

- JECFA (1989) in 1988 established a PTWI at 7 mg/kg body weight for the total intake, including food additive uses of aluminium salts.
- According to WHO (1993), no health-based guideline value is recommended in drinking water. However, directive 98/83/EC on the quality of water intended for human consumption gives a standard value of 0.2 mg/l for water for human consumption as a compromise between the practical use of aluminium salts in drinking water treatment and discoloration of distributed water.
- Average dietary intake in UK is 10 mg/person/day (MAFF, 1998). Certain pharmaceuticals can give an additional intake of aluminium.
- Exposure to aluminium is usually not harmful (ATSDR, 1997). Aluminium is excreted by the kidneys, and only a small amount of aluminium is absorbed (JECFA, 1989). However, soluble aluminium salts are more easily absorbed. Patients with impaired renal function treated by dialysis could show a higher aluminium blood level. In the past, some of these dialyzed patients have shown neurological symptoms of aluminium intoxication due to an inappropriate treatment which is no longer used; these symptoms have sometimes been mistaken for those of Alzheimer's disease. WHO (IPCS 1997) has concluded that aluminium is not the origin of Alzheimer's disease.

Conclusions and recommendations

- Storage of strongly acidic (e.g. fruit juices) or strongly salty, liquid foodstuffs in uncoated aluminium utensils should be limited in order to minimise migration.
- Labelling for users of uncoated aluminium should be given by the producer. The labelling, where appropriate could be: “User information. Do not use this utensil to store acidic or salty humid food before or after cooking” or “To be used for storing food in refrigerator only”.
- Guidance should be available from producers of uncoated aluminium utensils regarding the use of their product with strongly acidic or salty foodstuff.
- Manufactures should comply with the GMP for aluminium alloy semi products intended to come into contact with foodstuff.

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Guideline for chromium

Introduction

Chromium is found in the environment mainly in the trivalent form. Hexavalent chromium, or chromate, may also be found in very small amounts, arising usually from anthropogenic sources (Beliles, 1994). Cr(III) has the ability to form strong, inert complexes with a wide range of naturally occurring organic and inorganic ligands (Florence and Batley, 1980). In most soils and bedrocks, chromium is immobilised in the trivalent state (Florence and Batley, 1980). Chromium is an essential element to man. Chromium is found at low levels in most biological materials.

Main sources of chromium in the diet

The main sources of chromium are cereals, meat, vegetables and unrefined sugar, while fish, vegetable oil and fruits contain smaller amounts (Codex, 1995). Most foodstuffs contain less than 0.1 mg chromium per kg (Nordic Council of Ministers, 1995). Chromium is present in the diet mainly as Cr(III) (Codex, 1995). As with all metals, food contamination may be caused by atmospheric fall-out (Codex, 1995).

Metallic food contact materials

Chromium is found in some types of cans and utensils. In cans it serves to passivate the tinplate surface. Chromium is used in the production of stainless steel of various kinds and in alloys with iron, nickel and cobalt. Ferro chromium and chromium metal are the most important classes of chromium used in the alloy industry (Langaard and Norseth, 1986). Chromium containing stainless steels (see guideline on stainless steel) are important food contact materials used for transportation, e.g. in milk trucks, for processing equipment, e.g. in the dairy and chocolate industry, in processing of fruit such as apples, grapes, oranges and tomatoes, for containers such as wine tanks, for brew kettles and beer kegs, for processing of dry food such as cereals, flour and sugar, for utensils such as blenders and bread dough mixers, in slaughter-houses, in processing of fish, for nearly all of the equipment in big kitchens, such as restaurants, hospitals, electric kettles, cookware and kitchen appliances of any kind such as sinks and drains, for bowls, knives, spoons and forks. Chromium is also used to coat other metals, which are then protected from corrosion because of the passive film which forms on the surface of chromium.

Other food contact materials

Chromium compounds are found in pottery, glazes, paper and dyes (Langaard and Norseth, 1986).

Migration information

Canned foodstuffs in non-lacquered cans and other processed foodstuffs, particularly acidic foodstuffs such as fruit juices, may be significantly higher in chromium than fresh foodstuffs. A small contribution to chromium intake can be made by uptake from cans. However, the significance of this is probably negligible. Chromium from materials and articles is expected to migrate as Cr(III) and not as Cr(VI) (Guglhofer and Bianchi, 1991). Cr(III) can not migrate at neutral pH in foodstuffs. Therefore, the migration of Cr(III) to foods of pH 5 or above is low. Formation of Cr(VI) as a result of a conversion in water of Cr(III) is not possible. Therefore, formation of Cr(VI) does not occur in foodstuffs. This implies, that Cr(VI) is generally not

considered to be an issue of food contact materials. Also, chromium does not migrate significantly from articles made of stainless steel, and any released chromium is Cr(III) (Cunat, 1997). Due to alloying with chromium, the stainless steels resist corrosion by foods and are readily cleaned, thereby providing hygiene in food preparation and handling. Chromium is one of the metals which naturally forms a corrosion-resistant passive film when in contact with water and air (see section on corrosion in Introduction).

Safety aspects

- JECFA has not evaluated chromium.
- SCF found that the data on the essentiality and metabolism of chromium are so sparse that the Committee was unable to specify any requirements (SCF, 1993).
- WHO (1993) has set a maximum of 0.05 mg/l of Cr(VI) in drinking water.
- Recent estimates of the daily intake range from 0.025-0.2 mg/day (Codex, 1995).
- The speciation of chromium is of great importance for the toxicity. Cr(III), the most stable oxidation state in biological materials, is an essential element for normal glucose metabolism, while Cr(VI) is highly toxic (Beliles, 1994; Costa, 1997; Nordic Council of Ministers, 1995). Cr(III) has a low toxicity due to low absorption (about 0.5%) (Nordic Council of Ministers, 1995). Toxic aspects of chromium are related to Cr(VI) (Nordic Council of Ministers, 1995), due to its high absorption, easy penetration of the cell membranes and its genotoxicity and oxidising properties (Codex, 1995).

Conclusions and recommendations

Although there is no specific evaluation on chromium, it seems that anthropogenic chromium in foodstuffs is not a toxicological problem because the recommended intake is higher than actual values. However,

- A specific evaluation on chromium should be conducted, by for instance SCF, including evaluation on the aspect of allergy and chromium as at least one reference refers to chromium allergy (Veien et al., 1994).

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Guideline for copper

Introduction

Copper is found at a concentration of 70 mg/kg in the earth's crust (Beliles, 1994). Copper exists in two oxidation states: Cu(I) (cuprous) and Cu(II) (cupric). Copper can also occur in a trivalent state due to certain chemical reactions. Copper is among the most effective of metal biochemical oxidising agents. Copper is an essential element to man (Aaseth and Norseth, 1986). Copper also has the ability to restrict bacterial growth, e.g. Legionella, in drinking water systems (Rogers et al., 1994).

Main sources of copper in the diet

Copper is naturally present in most foodstuffs in the form of copper ions or copper salts (Codex, 1995). Generally, the concentration of copper in foodstuffs is about 2 mg/kg or less, the main sources being meat, offal, fish, pecans, milk chocolate and green vegetables (Aaseth and Norseth, 1986). However, levels up to 39 mg/kg is reported for liver and cocoa (see Appendix III).

Metallic food contact materials

Copper vessels are traditionally used in many specialised food processing activities, such as breweries and distilleries, for cheese-making, chocolate, dry vegetables, jam and sweets production. In food utensils, copper is in general used unalloyed, for example in saucepans, which are usually lined inside with tin or stainless steel. Copper is used in alloys, particularly brass, bronze, and nickel silver (British Non-Ferrous Metals Federation, 1997).

Other food contact materials

No information is available.

Migration information

Copper is slowly attacked by dilute hydrochloric acid or dilute sulfuric acid and is soluble in ammonia water (Beliles, 1994). Acidic foodstuffs can attack copper in utensils. Therefore, copper may be present in foodstuffs due to migration from food contact materials, e.g. copper utensils, copper pipes, etc. (Codex, 1995) or from using drinking water from copper pipes for food preparation. In some cases, high copper migration might induce some discoloration. Migration from copper into sugar confectionery cooked at 125-140 °C and at pH 5.1-6.0 on average increases the copper concentration in the confectionery from 0.13 mg/kg to 0.25 mg/kg (Written comments from BCCCA, 1999).

Safety aspects

- JECFA (1982) has established a PMTDI of 0.5 mg/kg body weight.
- The daily requirement is 0.05 mg/kg body weight set by JECFA in 1982.
- SCF (1993) has proposed an upper limit of 10 mg/day.
- WHO (1998) has set a provisional health-based guideline value for copper at 2 mg/l in drinking water as a result of uncertainties in the dose-response relationship between copper in drinking water and acute gastrointestinal effects in human.
- The average total dietary copper intake ranges in the order of 0.9-2.2 mg/day exceeding occasionally 5 mg/day (IPCS, 1998).
- There is greater risk of health effects from deficiency of copper intake than from excess copper intake. Acute toxicity due to ingestion of copper is infrequent in humans. However, when it occurs it is usually a consequence of the migration of copper into beverages (including drinking water) or from accidental or deliberate ingestion of high quantities of copper salts. Symptoms include vomiting, lethargy, acute hemolytic anaemia, renal and liver damage, neurotoxicity, increased blood pressure and respiratory rates. In some cases, coma and death followed (Environmental Health Criteria for Copper, 1996). Chronic copper poisoning has not been described in general population (Aaseth and Norseth, 1986).

Conclusions and recommendations

- The level of contamination of copper observed does not constitute a safety problem. It is recommended to avoid direct food contact with copper utensils when unacceptable organoleptic effects could take place. There is no recommendation or restriction for the use of copper coated with tin, stainless steel or another appropriate covering material. The general recommendation should be taken into account when evaluating individual food items in contact with copper utensils.
- The intentional migration of copper into for instance cheese, where copper is used as an active component, is considered elsewhere.

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Guideline for iron

Introduction

Iron is the fourth most abundant element (5%) in the earth's crust (Beliles, 1994). Iron is used for production of steel. The principal compounds of iron are ferrous, Fe(II) and ferric, Fe(III) (Beliles, 1994). Iron is essential for the synthesis of blood pigments. Under normal conditions the body contains about 4 g of iron (Beliles, 1994). Haemoglobin contains the greatest amount of body iron (67%), and this largely in the red blood cells (Beliles, 1994).

Main sources of iron in the diet

Iron is present in most foods and beverages. In general, liver, kidney, beef, ham, egg yolk, and soybeans have iron concentrations to the order of 30-150 mg/kg (Elinder, 1986). In several countries the cereal most commonly eaten, e.g., wheat flour, is fortified with iron in order to provide the necessary amount of iron in the diet (Nordic Council of Ministers, 1995).

Metallic food contact materials

Iron is used in a great variety of kitchen utensils. Iron is found in cans and can ends of steel, and in closure's mainly for glass bottles and jars. Also, iron as cast iron is used as pots and pans. Iron is the major constituent of steel, which also contains small quantities of certain other metals, such as chromium, manganese, molybdenum and nickel (Elinder, 1986). Iron is used in steel with a tin coating (tinplate), which is often used with an internal resin based coating, and steel with an electro-chromium coating always with an internal resin-based coating.

Other food contact materials

The several iron oxide forms are used as paint pigments (Beliles, 1994) of which some are permitted as direct food colours. The soluble salts are variously used as pigments in food contact materials (Beliles, 1994).

Migration information

Food contamination by iron may originate from food processing equipment, containers and other utensils used for foodstuff. The iron leaching to canned foodstuffs depends on storage time of the food product. Rare cases of release of very high quantities of iron from food contact materials such as iron kitchen utensils has been observed (Codex, 1995).

Safety aspects

- JECFA (1983) has established a PMTDI at 0.8 mg/kg body weight. The value applies to iron from all sources except for iron oxides used as colouring agents, supplemental iron taken during pregnancy and lactation and supplemental iron for specific clinical requirements. The value is 8 times lower than the acute toxic dose.
- SCF (1993) has evaluated iron mainly to be a deficiency problem.
- WHO (1993) has proposed, that no health-based guideline value is set for iron in drinking water.
- The recommended intake is 10-15 mg/day (Nordic Council of Ministers, 1995).

- The average intake is 15 mg/day (Beliles, 1994). A safety margin between the tolerable and the essential dose is only 4-6 for women.
- Iron is an essential trace metal (JECFA, 1983). Iron is mainly a deficiency problem and not a toxicological problem. Iron deficiency is generally acknowledged to be the most common, single nutritional deficiency in both developing and developed countries (Nordic Council of Ministers, 1995). Certain iron salts, mainly ferrous sulphate and ferrous succinate, are frequently used for the treatment and prevention of iron deficiency in humans (Beliles, 1994). Under normal conditions, about 5-15% of the iron is absorbed (Elinder, 1986). Ingestion of soluble iron salts by children in doses exceeding 0.5 g of iron can give rise to severe lesions in the gastrointestinal tract, followed by metabolic acidosis, shock and toxic hepatitis (Elinder, 1986).

Conclusions and recommendations

The levels of migration observed do not constitute a safety problem.

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Guideline for lead

Introduction

Lead is found as a contaminant in air, waters and soils (Codex, 1995). The earth's crust contains about 15 mg/kg of lead (Beliles, 1994). Lead is present in the environment in the form of metallic lead, inorganic ions and salts and organo-metallic compounds (CE, 1994). The sources of contamination are numerous including accumulators, petrol, recycling of lead batteries and combustion of industrial and household waste. Lead pollution is decreasing in most parts of the world, as lead-containing chemicals, such as tetraethyl lead and tetramethyl lead used as gasoline additives to increase octane rating, are replaced by other additives (ATSDR, 1997; Codex, 1995) and due to recycling of accumulators and batteries. Exposure through drinking water where lead or lead soldered pipes are still used may contribute significantly to the lead intake. The WHO Air Quality Guidelines for Europe indicate that airborne lead contributes about 1-2% of human intake. The greatest single use of lead metal today is in batteries for automobiles (Beliles, 1994). Most of the lead in the environment is present as complex bound lead ions in solution or as slightly soluble salts as Pb(II).

Main sources of lead in the diet

Lead in the soil is only poorly taken up by plant roots and is not transported away from the roots to the rest of the plant corp. Therefore, lead levels in the plant are to a large extent governed by air-borne lead contamination which makes leaves and leafy vegetables most vulnerable to the air-borne deposition, but also cereal grains have been shown to absorb substantial amounts of lead via the air (CCFAC, 1995). The main sources of lead intake are foodstuffs like vegetables (up to 0.05 mg/kg (National Food Agency of Denmark, 1995)), cereals and cereal products (up to 0.09 mg/kg (National Food Agency of Denmark, 1995)), fruit and fruit juices as well as wine, beverages and drinking water (Codex, 1995). Kidneys and shellfish may contain rather high amounts of lead (Codex, 1996).

Metallic food contact materials

Canned foodstuffs previously contained markedly higher lead levels than fresh foodstuffs; this was most evident in fruits (Tsuchiya, 1986). However, modern canning techniques without lead soldering are now normally used (Tsuchiya, 1986), which has caused a decrease in lead intake from this source. Some parts of the world still produce lead-soldered cans. Metallic lead in food is likely to be restricted to the presence of lead from shot or partially jacketed bullets in game (CE, 1994). Lead is also found in lead solder used to repair equipment. Manufacturing equipment and household utensils may contain parts made wholly or partly of lead, and such parts may release lead if in contact with food. Lead pipes or lead solder used to repair equipment have also caused contamination problems. Pewter may also release lead, which may be found as a contaminant in pewter.

Other food contact materials

Previously, lead pigments were often used in ceramic glazes (Beliles, 1994). However, because lead pigments are toxic, their use is now restricted. In EU, migration is now regulated by Directive 84/500/EEC which sets strict limits for the release of lead from materials and articles made of ceramics. Only imported products from some countries and handicraft still need particular attention. White lead is the most important lead pigment (Beliles, 1994). Also, crystal glass typically contains 24% lead.

Migration information

The information on migration of lead from metallic food contact materials is limited. The only information available is that lead resists attack by many acids, including sulfuric acid (Beliles, 1994).

Safety aspects

- JECFA (1993) has established a PTWI at 0.025 mg/kg body weight.
- SCF at its 91st meeting held on December 9-10, 1993 agreed with the JECFA conclusion.
- WHO (1993) has set a health-based guideline value for lead in drinking water at 0.01 mg/l.
- Estimated daily dietary intake for adults range from 0.015-0.1 mg, depending on the composition of the diet and where the consumer lives (Codex, 1995).
- For the general population, exposure to lead occurs primarily via the oral route with some contribution from the inhalation route (ATSDR, 1997). Lead is mainly absorbed from the gastrointestinal tract (CE, 1994). Children absorb more efficiently than adults in this way. While lead absorption for adults normally will be approximately 5-10%, children may absorb up to 40% of ingested lead (CE, 1994). Lead in the blood has a half-life of about a month, whereas some compartments of the bone may have a half-life as long as 27 years (Beliles, 1994). The toxicity of lead is based on its ability to bind biologically important molecules and thus to interfere with their function (CE, 1994). The most common form of acute lead poisoning is gastrointestinal colic (Beliles, 1994). Lead compounds are not considered carcinogenic to man (Tsuchiya, 1986).

Conclusions and recommendations

- Due to the low safety factor, all use of lead in food contact materials should be abandoned or avoided. Parts made wholly or partly of lead and lead solder for repair should not be used in materials and articles intended to come into contact with foodstuffs including the use of lead in soldered cans. Consequently, limits for lead in foodstuffs should not include special allowances for canned foodstuffs.

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Guideline for manganese

Introduction

Manganese is an essential element widely distributed in the environment (Codex, 1995), comprising approximately 0.1% of the earth's crust (Florence and Batley, 1980). About 90% of the total manganese production is used in steel manufacture as a deoxidising and desulphurising additive and as an alloying constituent (Beliles, 1994; Saric, 1986). Manganese exist in two common oxidation states, as manganese (II) and manganese (IV) (Florence and Batley, 1980).

Main sources of manganese in the diet

Manganese is present in most foodstuffs. The main contributors of manganese to the diet are cereals (10-30 mg/kg) as well as vegetables and fruits (0.5-5 mg/kg) (Beliles, 1994; Codex, 1995). Nuts may have a high content of manganese. In some countries, manganese has replaced organic lead as an additive in petrol. This might result in increasing concentrations of manganese in the environment and in foodstuffs in the future.

Metallic food contact materials

Manganese is used in steel and other alloys (Saric, 1986).

Other food contact materials

Manganese is used in the manufacture of glass to bleach the colour of any iron present (Saric, 1986). Manganese is used in pigments, glazes, and other products.

Migration information

Migration of manganese from six types of stainless steels containing 0.21-2.0 wt % manganese was examined in drinking water and in waters with 500 mg/l chloride or 3 mg/l "free" chlorine. The migration of manganese was below 0.002 mg/l in all tests (Lewus et al. 1998).

Safety aspects

- JECFA has not evaluated manganese.
- WHO (1993) recommends a daily intake of 2-3 mg/day.
- SCF (1993) recommends 1-10 mg/day as the acceptable range of intake.
- SCF (1996) recommends a maximum limit of 0.5 mg/l for manganese in natural mineral waters.
- The average intake is 2-3 mg/day (SCF, 1993).
- According to WHO drinking water guideline (1993) effects can be seen after doses ranging from 1-150 mg/kg body weight. WHO (1993) recommends a provisional health-based guideline value of 0.5 mg/l for drinking water.
- Manganese is an essential trace element that plays a role in bone mineralization, protein and energy metabolism, metabolic regulation, cellular protection from damaging free radical species, and the formation of glycosaminoglycans (ATSDR, 1997). Although manganese is an essential nutrient, exposure to high levels via inhalation or ingestion may cause some

adverse health effects (ATSDR, 1997). Excess manganese affects the central nervous system and the neurological effects have been observed in case of occupational exposure. No problems are reported in connection with intake of manganese with foodstuff as manganese is considered one of the least toxic metals. Consistent with its role as an essential element, manganese and its inorganic compounds have a relatively low order of acute toxicity (Beliles, 1994). However, the absorption is increased in individuals with iron deficiency (Beliles, 1994). In humans, the degree of manganese absorption from the gastrointestinal system is generally low, to the order of 3 % (Beliles, 1994).

Conclusions and recommendations

- Although there is no specific evaluation on manganese, it seems that manganese in food contact materials does not give rise to any problems. Therefore,
- No specific recommendation concerning migration is needed.
- A specific evaluation on manganese should be conducted.

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Guideline for nickel

Introduction

Nickel, combined with other elements, occurs naturally in the earth's crust, is found in all soils, and is also emitted from volcanoes. Nickel is the 24th most abundant element, and in the environment nickel is found primarily as oxides or sulfides (ATSDR, 1995). There has been a growing interest in possible effects of nickel in foodstuffs, i.e. a possible worsening of nickel-related dermatitis. Nickel is probably an essential element for biological organisms (ATSDR, 1995), even though nickel deficiency has not been demonstrated in human beings (Beliles, 1994).

Main sources of nickel in the diet

Nickel is found in small quantities in many foodstuffs (0,001-0,01 mg/kg) and in higher concentrations in foodstuffs such as grains, nuts, cocoa products and seeds (up to 0,8 mg/kg) (National Food Agency of Denmark, 1995). In the diet it is found as complex bound Ni²⁺-ions (Codex, 1995).

Metallic food contact materials

87% of the world-wide production of nickel is used for the manufacturing of alloys and 9% for plating (NiDI, 1996). There are at least 3000 different alloys containing nickel. The major use of nickel is in the production of high quality, corrosion resistant alloys with iron, copper, aluminium, chromium, zinc and molybdenum. Nickel-containing stainless steel is strongly corrosion-resistant. Most nickel-containing food contact materials are stainless steels. Nickel-containing stainless steels (see guideline on stainless steel) are important food contact materials used for transportation, e.g. in milk trucks, for processing equipment, e.g. in the dairy and chocolate industry, in processing of fruit such as apples, grapes, oranges and tomatoes, for containers such as wine tanks, for brew kettles and beer kegs, for processing of dry food such as cereals, flour and sugar, for utensils such as blenders and bread dough mixers, in slaughter-houses, in processing of fish, for nearly all of the equipment in big kitchens, such as restaurants, hospitals, for electric kettles, cookware and kitchen appliances of any kind such as sinks and drains, for bowls, knives, spoons and forks. A potential source of nickel intake is from nickel-plated food contact materials such as kitchen utensils and nickel plated heating coils in electric kettles.

Other food contact materials

Nickelous oxide, NiO, is used in the production of enamel frits and ceramic glazes, and in glass manufacture (Beliles, 1994). Basic nickel carbonate is used in colouring ceramics and glazes (Beliles, 1994).

Migration information

Nickel-plated items are less durable, less corrosion resistant than stainless steel and are therefore not commonly used for articles in contact with food and drink. The release of nickel ions from stainless steel cooking pots is generally less than 0.1 mg/kg (NiDI, 1994). Electrical water kettles and immersion heaters with open nickel plated heating coils can release nickel-amounts up to 0.6 mg/l, especially after descaling.

Safety aspects

- JECFA has not evaluated nickel.
- WHO (1997) has given a TDI of 0.005 mg/kg body weight.
- WHO (1997) has set a provisional health based guideline value at 0.02 mg/l for drinking water.
- According to SCF (1993) some studies in animal models suggest that nickel may be essential, but the current data are not sufficiently conclusive to justify setting any recommended intakes.
- The daily intake of nickel via foodstuff is estimated at 0.15-0.7 mg/day (Codex, 1995).
- The dietary intake due to migration from metal cook ware is estimated to be 0.1 mg/day (NiDI, 1994).
- The absorption and retention of nickel in the gastrointestinal tract is influenced by fasting and food intake. Food intake and gastric emptying are of substantial significance for the bio-availability of nickel from aqueous solutions. The absorption of free nickel ions released in the gastrointestinal tract may be 40 times higher than that of complex-bound nickel from foodstuff (Sunderman et al., 1989). The absorption of nickel from drinking water is increased by fasting (Nielsen et al., 1999). Inorganic nickel compounds are absorbed to 10% or less from the gastrointestinal tract (Norseth, 1986). Nickel intake via foodstuff does not cause hazards for the majority of consumers (Codex, 1995). A subgroup of the population (app. 10%, mainly women) have contact allergy to nickel. Nickel allergy is only caused by absorption of nickel through the skin (Codex, 1995). Use of stainless steel utensils by nickel sensitised persons does not elicit an allergic reaction. Thus, there is no advantage to be gained by nickel sensitised persons in avoiding the use of stainless steel utensils (Cunat, 1997). However, some patients with certain types of nickel dermatitis may get a flare-up of eczema through ingestion of even small amounts of orally ingested nickel e.g. from foodstuffs rich in nickel or foodstuff or drinks contaminated via nickel containing materials (Veien, 1989; Veien and Menné, 1990).

Conclusions and recommendations

Although there is no specific evaluation on nickel, it seems that soluble nickel released from contact material is more readily absorbed than complex-bound nickel from foodstuff. Therefore, the contamination of foodstuff and drink from nickel containing food materials, e.g. kitchen utensils and electric kettles should be reduced.

- The migration of nickel to foodstuffs should be as low as reasonably achievable and no more than: 0.1 mg/kg as a general limit of migration into foodstuffs and 0.05 mg/l from electric kettles. In the case of stainless steel, these values can safely be reached if, before initial cooking (first use of new items), the food contact items are exposed to boiling water and the water is discarded.
- The frequency of descaling of electric kettles and immersion heaters should be as low as possible and the first five cooking waters should be discarded.
- New electric kettles should be charged with fresh water, brought to the boil, and emptied 2-3 times before being put to normal use.
- Water should not be left standing in the electric kettle and then reboiled for use/consumption.
- Nickel-plated food contact materials should not be used.

- Nickel-containing food contact materials with the exception of stainless steel should be labelled to ensure that the product meet the above recommendations.

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Guideline for silver

Introduction

Pure silver has the highest thermal and electrical conductivity of all metals. Silver alloyed with 7.5% copper is known as sterling silver (Beliles, 1994).

Main sources of silver in the diet

Silver may be ingested via consumption of marine organisms containing low concentrations, and in small amounts released from dental fillings (Fowler and Nordberg, 1986). Silver salts, because of their germicidal properties, are in some countries used as drinking water disinfectants (Beliles, 1994; Fowler and Nordberg, 1986). Also, silver is used as a colouring agent for decorations for confectionary and in alcoholic beverages. .

Metallic food contact materials

Silver is used in the production of cutlery and tableware (Fowler and Nordberg, 1986). Attention should be paid to the European standards EN ISO 8442-2 and EN ISO 8442-3 which apply to silver-plated nickel silver, or silver-plated stainless steel cutlery and to silver-coated brass, copper, nickel-silver, pewter and stainless steel hollow-ware and attachments thereto, respectively.

Other food contact materials

No information is available.

Migration information

The information on migration of silver is limited. Pure silver is a moderately soft metal (Beliles, 1994). Chemically, silver is the most reactive of the noble metals, but it does not oxidize readily; rather it "tarnishes" by combining at ordinary temperatures with sulfur or H₂S. Oxidizing acids, nitric or sulfuric, oxidize silver to the unipositive ion, the form in which it exists in most of its compounds (Beliles, 1994).

Safety aspects

- JECFA has not evaluated silver.
- WHO (1993) has proposed no health-based guideline value for silver in drinking water. The levels of silver in drinking water are generally below 0.005 mg/l.
- Estimated daily intake is 0.007 mg (WHO, 1993).
- Silver salts may be absorbed by up to 10-20% following ingestion (Fowler and Nordberg, 1986). The biological half-life for silver ranges from a few days for animals up to about 50 days for the human liver (Fowler and Nordberg, 1986). Water-soluble silver compounds such as silver-nitrate have a local corrosive effect and may cause fatal poisoning if swallowed accidentally. Repeated exposure to silver may produce anaemia, cardiac enlargement, growth retardation, and degenerative changes in the liver (Fowler and Nordberg, 1986).

Acute human toxicity from silver is unknown, but some silver compounds such as silver oxide and silver nitrate are irritating, and exposure is associated with nosebleeds and abdominal cramps (Beliles, 1994).

Conclusions and recommendations

Although there is no specific evaluation on silver, it seems that there is no need for recommendations for the use of silver. However,

- A specific evaluation on silver should be conducted.
- Silver reacts with sulphide forming the black silver sulphide which has an unpleasant taste. This reaction might occur when eating eggs with silver spoons.

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Guideline for tin

Introduction

Tin occurs in the earth's crust with an average abundance of 2 mg/kg and is concentrated in areas of tin-bearing minerals (Beliles, 1994). Tin occurs in the earth's crust mainly as cassiterite or tinstone (SnO_2), which is the main source of tin production (Beliles, 1994). Combustion of fossil fuels releases tin into the air (Codex, 1998). Secondary tin sources are tin plate scrap, solders and other alloys. Some tin is recovered from cans (Magos, 1986).

Main sources of tin in the diet

Tin is present in the diet only in small quantities of complex bound Sn(II)-ions (Codex, 1995). Tin occurs in most foodstuffs. Levels are generally less than 1 mg/kg in unprocessed foodstuffs. Higher concentrations are found in canned foodstuffs from dissolution of the tinplate to form inorganic tin compounds or complexes (Codex, 1998). Codex (1998) suggests a maximum limit of 250 mg/kg for tin in solid foods in cans and a maximum level of 200 mg/kg for liquid foods in cans. Stannous chloride is authorised as a food additive for canned and bottled asparagus up to 25 mg/kg (as tin) according to Directive 95/2/EC.

Metallic food contact materials

The present major source of tin in the diet is food contact materials; especially the release from tin cans to acidic foodstuffs (Codex, 1995). Tin cans are actually steel cans with a thin coating of metallic tin (tinplate) (Beliles, 1994). There is often an internal resin-based coating on the tinplate. Tinplate is mainly used in cans, can ends, and closures mainly for glass bottles and jars. However, the use of tin in cans has in the latest years been decreasing in Europe and the USA. Tin is also found in pewter. Tin is used in alloys, e.g. with copper for conversion into bronze and with zinc for galvanisation (Beliles, 1994). Tin is also used to coat kitchen utensils.

Other food contact materials

Inorganic tin compounds are used as pigments in the ceramic industry (Magos, 1986). Organotin compounds stabilize a number of industrial substances that contain chlorine: polyvinyl and polyvinylidene chloride plastics, chlorinated rubber and modified plastics (Beliles, 1994).

Migration information

Tin is amphoteric, reacting with both strong acids and bases, but is relatively unreactive to nearly neutral solutions (Beliles, 1994). The presence of oxygen greatly accelerates reaction in solution (Beliles, 1994).

Tin plate used in food containers is only slowly oxidised. The tin content in foodstuffs depends on:

- Whether the tin cans are laquered
- The presence of any oxidizing agents or corrosion accelerators (nitrate, for example)
- The acidity of the product in the tin can
- How long, and at what temperature, the tin cans are stored before being opened

- The length of time the product is kept in the tin can after it has been opened.

The oxidation of the tinfoil followed by unavoidable migration of the tin ions formed into the foodstuff is the physiochemical mechanism, known as the sacrificial anode effect, which protects the underlying steel from being corroded by the foodstuff. The dissolution of the tin protects the can from possible perforation, and protects the contents from degradation (changes in colour and flavour) during heat sterilisation and storage, which is a typical shelf life of 2 years. Tin concentrations in foodstuffs in unlacquered cans may exceed 100 mg/kg while foodstuffs stored in lacquered cans have tin levels generally below 25 mg/kg (Codex, 1998). However, storing foodstuffs in opened unlacquered cans result in substantial increases in the tin concentration in foodstuffs (Codex, 1998). Canned vegetables and fruits in unlacquered cans make up only a small percentage by weight of total food intake, while they may contribute 85% of the total intake of tin. The lacquer coating thickness greatly affects the performance of the lacquered food can.

For dipped and electroplated tin, an oxide film forms on the tin in air. The film is fairly stable and provides a barrier to further oxidation. At pH values between 3-10 and in the absence of complexing agents, the oxide barrier protects the metal from food. Outside this pH range, however, corrosion of the tin occurs (Murphy and Amberg-Muller, 1996).

Pewter may also release lead, which may be found as a contaminant in pewter.

Safety aspects

- JECFA (1989) has in 1988 established a PTWI at 14 mg/kg body weight per week including tin from food additives. JECFA also states, that "tin levels should be as low as practicable because of possibility of gastric irritation".
- WHO (1993) has concluded, that because of the low toxicity of inorganic tin, a tentative guideline value could be derived three orders of magnitude higher than the normal tin concentration in drinking water. For this reason, the establishment of a numerical guideline value for inorganic tin was deemed not necessary.
- A normal diet without canned foodstuff or beverage contains approximately 0.2 mg tin per day (Codex, 1995). The total average intake of tin is 4 mg/day (Beliles, 1994).
- Codex (1998) suggests a maximum limit of 250 mg/kg for tin in solid foods in cans and a maximum level of 200 mg/kg for liquid foods in cans.
- National legislation in member states includes maximum limits in the range 50-250 mg/kg.
- There are no indications of chronic toxicity of tin in humans (Codex, 1995). Inorganic tin compounds, especially the environmentally dominant tetravalent tins, are poorly absorbed from the gastrointestinal tract (Magos, 1986). Tin compounds act as an irritant for the gastrointestinal tract mucosa, causing nausea, vomiting, diarrhoea, fatigue and headache (Codex, 1998). The number of cases of tin poisoning in humans is limited. Cases of tin poisoning have been reported following the consumption of canned fruit juices, tomato juice, cherries, asparagus, herrings and apricots. The concentrations of tin in the products thought to have been associated with the incidents of acute poisoning were uncertain in many cases, but were probably in the range of 300-500 mg/kg (WHO, 1980). Tin appears to interfere with iron absorption and haemoglobin formation. Tin also has an inhibitory effect on copper, zinc and calcium absorption (Codex, 1998). Chronic exposure to high levels of tin may result in growth depression and altered immune function, possibly due to interactions between tin and zinc or selenium (Codex, 1998).

Conclusions and recommendations

At present, there are various maximum limits for tin in foodstuffs within the European countries (150-250 mg/kg). Therefore, harmonisation of the maximum levels for tin in foodstuffs is needed. Tin was prioritised by Codex for evaluation by JECFA in 2000 with respect to the acute toxicity. However, JECFA has not been in a position to make the evaluation due to lack of toxicological data.

- It is recommended that setting maximum limits for tin is pending an evaluation by JECFA and a decision in the Codex Committee on Food Additives and Contaminants or an evaluation by the EU Scientific Committee on Food (SCF).
- Food contact with tin materials should be avoided at low pH and high temperatures other than for food packaged in tin plated cans.
- Food storage in opened tin plated cans should be advised against.

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Guideline for titanium

Introduction

Titanium is the ninth most common element in the earth's crust and occurs in a number of minerals (Beliles, 1994). Titanium is a silvery grey metal resembling polished steel (Beliles, 1994). There is no evidence indicating that titanium is an essential element for man (Nordman and Berlin, 1986).

Main sources of titanium in the diet

Titanium is used in the form of the dioxide as a colour additive in confectionary, dairy products and soft drinks, etc. (Directive 95/2/EC). Also, titanium is used as additives to edible inks, toothpaste, and pharmaceuticals (Whitehead, 1991).

Metallic food contact materials

Titanium is often used in the form of alloys, which are stronger and more resistant to corrosion than the metal itself (Nordman and Berlin, 1986). However, the use in food contact materials is unknown. Titanium has been suggested to be used for corrosive or delicate liquids such as dairy products, fruit juices and in the wine industry (Feliciani et al., 1998). Titanium is also used in certain so-called "stabilized" forms of stainless steels, which in general contain less than 1%.

Other food contact materials

The extreme whiteness and brightness of titanium dioxide has led to the extensive use as white pigments in paints, lacquers, enamels, paper-coatings and plastics (Beliles, 1994; Nordman and Berlin, 1986). Also, titanium compounds are used as catalysts in the manufacture of plastics.

Migration information

Titanium seems to be practically inert, due to the phenomenon of passivation of the titanium surface by the formation of a molecular layer of TiO_2 . This layer, which is very adherent to the metallic substrate, is scarcely removed even by aggressive 3% v/v acetic acid solution saturated with 18-20% sodium chloride (Feliciani et al., 1998).

Safety aspects

- JECFA has not evaluated titanium.
- The estimated intake of titanium is 0.3-1 mg/day (Beliles, 1994; Whitehead, 1991).
- Titanium compounds are generally considered to be poorly absorbed upon ingestion (Nordman and Berlin, 1986). Studies on titanium alloys used in implants, and titanium compounds used in cosmetics and pharmaceuticals do not indicate any local effects on tissues (Nordman and Berlin, 1986). A distinct toxicological dichotomy exists between TiO_2 , the insoluble, unreactive non-metabolized form devoid of toxicity, and the soluble, inorganic salts that metabolize normally with absorption, distribution, and excretion (Beliles, 1994). However, little information exists on how titanium acts as a toxic agent, and what does exist is of little or no value in understanding the toxic actions of titanium (Beliles, 1994).

Conclusions and recommendations

Titanium (titanium dioxide) has been evaluated as a food additive. Based on this evaluation it seems that no recommendations are needed.

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Guideline for zinc

Introduction

Zinc is an essential trace metal (Elinder, 1986). Zinc is the 25th most abundant element and is widely found in nature (Beliles, 1994). Zinc appears in the form of zinc ions or zinc salts (Codex, 1995). Galvanising, a process involving the coating of iron and steel with zinc and to prevent corrosion, is the most important use of zinc (Beliles, 1994). Zinc protects iron from rusting because it is the stronger reducing agent of the two metals (Beliles, 1994).

Main sources of zinc in the diet

Zinc occurs in most foodstuffs and beverages (ATSDR, 1992). The main contributors to zinc intake are meats, especially organ meats, whole grain cereals and milk products including cheese (Codex, 1995). Oysters and peanuts may contain up to 100 mg/kg and 30 mg/kg, respectively.

Metallic food contact materials

Major uses of zinc are in the production of non-corrosive alloys, brass and in galvanised steel and iron products (Elinder, 1986). A common use of metallic zinc is to coat iron or other metals so that they do not rust or corrode (ATSDR, 1992). Metallic zinc is also mixed with other metals to form alloys such as brass and bronze (ATSDR, 1992). Galvanised products are widely used as household appliances (Elinder, 1986). Zinc may contain small amounts of more toxic metals, e.g. cadmium (0.01-0.04%) and lead as impurities (Elinder, 1986). The use of consumer articles with food contact made of zinc, zinc alloys or galvanised zinc is limited.

Other food contact materials

Zinc sulfide is grey-white or yellow-white, and zinc oxide is white. Both of these salts are used to make white paints, ceramics, and several other products (ATSDR, 1992).

Migration information

Zinc is a relatively soft metal and has a strong tendency to react with inorganic compounds, e.g. oxides, as well as organic ones (Elinder, 1986). Galvanised iron containers holding acidic drinks such as orange juice or alcoholic beverages have resulted in a number of reports of poisoning. Zinc is easily dissolved in diluted acids and by bases (Beliles, 1994) and under these circumstances, therefore zinc galvanised utensils may release zinc and cadmium. They can also release zinc hydrocarbonate in confined spaces where there is a combination of air and humidity.

Safety aspects

- JECFA (1982) has established a PMTDI of 1 mg/kg body weight.
- The required daily intake for adults is about 15 mg/day, however, the requirement varies with age (JECFA, 1982).
- According to SCF (1993) it would be unwise to exceed a daily intake of 30 mg in adults.
- The average daily intake is 15-20 mg/day (WHO, 1993).
- WHO (1993) stated that derivation of a health-based guideline value for drinking water is not required. However, drinking water containing levels above 5 mg/l may not be acceptable to consumers.
- Zinc is one of the most ubiquitous of the essential trace metals (Florence and Batley, 1980). The absorption of ingested zinc is highly variable (10-90%) (Elinder, 1986). Zinc is an essential element necessary for the function of a large number of metalloenzymes (ATSDR, 1992; Beliles, 1994). Zinc acts to diminish the toxicity of cadmium and copper (Florence and Batley, 1980). Zinc may be a modifier of the carcinogenic response; zinc deficiency or excessively high levels of zinc may enhance susceptibility to carcinogenesis (Beliles, 1994).

Conclusions and recommendations

Zinc has a high solubility by contact with acidic foodstuffs. The use of zinc, zinc alloys or zinc galvanised consumer goods with food contact is banned in some countries. Exceptions from the banning is zinc alloyed containers for oil or such containers made of galvanised zinc, zinc galvanised baskets for bakery products, etc. Therefore:

- Zinc should not be used in contact with wet or humid acidic foodstuffs.
- Zinc galvanized utensils must not contain cadmium or release cadmium.
- Zinc galvanised utensils can be used in contact with dry foodstuffs and with non-acidic foodstuffs.

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Guideline for alloys other than stainless steel

Introduction

An alloy is a metallic material homogeneous on a macroscopic scale, consisting of two or more elements so combined that they cannot readily be separated by mechanical means. The individual metal atoms present in a given alloy, interdiffuse and bond at the atomic level, producing new microstructures that give each alloy unique and specific properties.

The individual metals in an alloy do not exert their properties in the same way as when they are used as a single metal. During alloy manufacture, the elements used to make the alloy (“alloying elements”) react with and dissolve into each other to form alloys consisting of new crystalline structures and compounds with new properties. These structures and properties are retained as the alloys cool to room temperature. In particular, most alloys are more resistant to corrosion than their constituent metals. Thus, in the absence of migration information on the individual alloys, the migration of the metallic ions from the alloys can with respect to the safety aspects be evaluated as migration of the individual constituting metallic elements on a case by case basis. The contents of the individual metals may differ in alloys sold under the same names. This is because national and international specification standards give allowed concentration ranges for the different elements (eg stainless steel grade 316 may contain 16-18% of chromium, 10-14% of nickel and 2-3% of molybdenum, according to the specifications). Within the ranges given in the standards, the properties of the named alloy will be the same. This guideline only contains general information on some typical alloys. Please notice the separate guideline on stainless steel.

Main types of alloys

Most metals are mainly used in alloy form. Among the commonest alloys are:

- Stainless steels are iron-chromium alloys which contain a minimum of 10.5% chromium (usually 17-18%), less than 2% carbon and which are often also alloyed with other elements such as nickel, molybdenum etc. to provide desired properties (see Guideline for stainless steel).
- Bronze consists of 80-95% copper and 5-20% tin.
- Brass consists of 60-70% copper and 30-40% zinc.
- German silver is an alloy based on copper, nickel and zinc with for example a composition of 60% copper, 20% nickel and 20% zinc.
- Other alloys are used in small quantities for example nickel-titanium, nickel-copper, and quasi crystal.

A range of elements can be used as additions in different alloys. For example, in aluminium alloys, low levels of manganese, silicone or copper can be encountered, giving significant effects on the alloy properties (Beliles, 1994).

Metallic food contact materials

Presumably, only alloys listed are used in food contact materials.

Migration information

Compared with pure metals, alloys behave differently in a given foodstuff and in general this helps to reduce the migration of metallic ions while increasing the chemical stability of the products.

Migration tests have been carried out on coffee-pots (mocha type) with different composition of aluminium alloys. The coffee pots consisted of an alloy containing 0.09-0.77% zinc, 0.19-5.5% copper, 0.02-0.5% lead as well as other metallic elements. The migration of copper, zinc and lead was determined. The results showed, that increasing amounts of copper in the starting alloy did not correspond to increased copper migration level. Also, repeated use gave irregular but decreasing migration of all the tested metals (Gramiccioni et al., 1996).

Safety aspects

- There are no specific toxicological evaluations of the individual alloys used for direct food contact.
- The constituting elements of an alloy migrate from the alloy as the individual elements.
- The migration of the constituting elements is in general lower compared to migration from non-alloyed metals due to the microstructural binding of the elements in the alloys. Migration of an element from an alloy is controlled by the atomic binding forces within the alloy. In most alloys the constituent elements are chemically bound together, essentially forming new compounds at the microstructural level. This chemical binding anchors the constituent elements in place throughout the alloy and they are not free to migrate independently to the surface or through the surface (EIMAC, 1997). The composition of some alloys can minimise the migration of some of the metals as well as increase the chemical stability of the products compared to the migration from the pure metals. Therefore, compared with pure metals, alloys behave differently in a given foodstuff and, in general, this helps to reduce the migration of metallic ions while increasing the chemical stability of the product.
- All alloys should preferably be evaluated individually with respect to migration.
- Upon testing migration from alloys, the migration of the individual elements should be evaluated on the basis of the toxicological information on the individual elements.

Conclusions and recommendations

- Preferably, each alloy should be evaluated specifically, independently of the constituent metallic elements.
- Data on migration from the individual alloys used as food contact materials are needed.
- In the absence of a safety evaluation of an alloy, the migration of the individual elements should be evaluated. Following this, the migrated elements should be evaluated according to the guidelines on the individual elements.
- Alloys for food contact should contain only aluminium, chromium, copper, gold, iron, magnesium, manganese, molybdenum, nickel, platinum, silicone, silver, tin, titanium, zinc, cobalt, vanadium and carbon.

- Alloys used for solders which may come into contact with food should contain a maximum of 0.5% cadmium. Cadmium may not be intentionally added.

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Guideline for stainless steel

Introduction

Stainless steels are widely used in food contact applications. This is largely because of the corrosion resistance of stainless steels coupled with their strength and durability, their ability to be readily cleaned and sterilised without deterioration using a wide range of cleaning/sterilising systems, and the fact that they impart neither colour nor flavour to foodstuffs and beverages.

“Steel” is an alloy of iron and carbon (less than 2% carbon) which contains other elements (such as manganese, silicon and sulfur) for control of, or improvements in, properties. Such steel is often called “carbon steel”. Other elements can be added to develop special properties (e.g. up to 3% nickel, chromium and/or molybdenum) to give “alloy steels” for engineering purposes. Stainless steels¹ comprise a group of special steels with an even higher alloy content, to impart the corrosion resistance which renders them “stainless”. They are steels with a wide variety of compositions but always containing a high percentage of chromium (a minimum of 10.5%) as this is the alloying element of prime importance for conferring the typical corrosion resistance of stainless steels. In practice, the majority of the stainless steels used in food contact applications contain around 18% of chromium as this has been found to be the optimum concentration for corrosion resistance in a wide range of food and beverage media. It is also a concentration which is ideal in terms of cost and ease of fabrication (EUROFER, 1998). There are over 200 types (grades) of stainless steel, but only about 100 types are in regular commercial production and fewer than 10 types account for the bulk of usage.

Main types of stainless steel

Stainless steels are sub-divided into families according to their metallurgical structure. The stainless steel grades commonly used for food contact applications will generally fall into one of these families (figures supplied by the industry):

1. Martensitic stainless steels: 10.5-15% chromium (0-2%) or medium (4-6%) nickel. Furthermore, they may contain molybdenum (up to 1.3%) and vanadium (up to 0.2%). Sub-families with varying amounts of carbon \pm molybdenum are used for particular applications. Some typical compositions and applications are:
 - 13% chromium, 0.2% carbon, no nickel or molybdenum, used for medium price cutlery.
 - 13% chromium, 0.4% carbon, plus molybdenum, used for high quality cutlery.
 - 14-15% chromium, >0.4% carbon, 0.5-0.8% molybdenum, 0.1-0.2% vanadium, no nickel, used for cooks' knives and professional knives.
2. Ferritic stainless steels: minimum 10.5% chromium and maximum 1 % nickel. Some grades may contain up to 4% molybdenum and aluminium may be used as an alloying element.
 - 17% chromium, used for low price cutlery, hollow-ware, table surfaces, panels and worktops.

¹ Stainless steels are defined according to the European Standard EN 10088 (British Standards Institution, 1995).

3. Austenitic stainless steels: minimum, for food contact applications, 16% chromium and 6% nickel. Austenitic grades with varying amounts of chromium and nickel, sometimes with other elements (e.g. molybdenum, copper), are used for particular applications.
 - Austenitic stainless steel grades are used in a very wide range of food contact applications, both domestic and industrial (cutlery, hollow-ware and kitchen utensils typically 18% chromium and 8-10% nickel; while higher alloy grades e.g. 17% chromium, 11% nickel and 2% molybdenum, are used for food processing, storage and transport equipment, pipe-work etc.). Grades containing molybdenum (approx. 2%, or 4.5%) are particularly resistant to the corrosion caused by salt-containing foods.
4. Austeno-ferritic steels, also known as Duplex steels: Contain 21-28% chromium, 0-4.5% molybdenum, 3.5-8% nickel, 0.05-0.3% nitrogen and up to 1% tungsten. These stainless steels may be used in contact with aggressive foodstuffs as they have a very high resistance to corrosion caused by, for example, saline solutions at high temperatures. Super-austenitic grades are used in similar applications and also for steam heating systems, boilers, etc.

Composition limits

There are no universal composition limits for stainless steels to be used in food contact applications. There are legislative requirements in France and Italy. In France, stainless steels for food contact products must contain at least 13% of chromium, and can contain nickel and manganese. Maximum limits are imposed for certain other alloying elements (4% for Mo, Ti, Al and Cu; 1% for Ta, Nb and Zr). In Italy, there is a “positive list” of stainless steel grades for food contact. These grades must pass tests for corrosion in distilled water, olive oil, an aqueous solution of ethanol and 3% acetic acid in water, under specified conditions. New grades can be added to the list following appropriate testing. In the UK, there are numerous specifications for a wide range of food contact applications for stainless steels. Other countries also have similar regulations. References to some of the Italian, French, UK and German legislation/standards are given below.

In addition, there are European standards for certain types of application of stainless steels. The composition limits for stainless steel for table cutlery are set by EN ISO 8442-2. The composition depends on the application of the table cutlery. The ranges of the compositions are as follows:

Composition limits for stainless steel for table cutlery according to EN ISO 8442-2.

Type	Composition (%)					
	C	Cr	Ni	Mo	Mn	V
Martensitic	≤ 0.16	≤ 12	0	-	-	-
	≤ 0.26	≤ 12	-	≥ 1.3	-	≥ 0.2
Ferritic	≥ 0.07	≤ 16	0	≥ 1.3	-	-
Austenitic	≥ 0.07	≤ 17	≤ 8	≥ 2	-	-
	≥ 0.15	≤ 17	≤ 4	-	≥ 10.5	-

The table below gives compositional information on some other grades of stainless steels used in food contact applications:

Type	Grade	Composition (%)*					
		C	Cr	Ni	Mo	Cu	V
Martensitic	1.4028	> 0.15	12-14	-	-	-	-
	1.4116	> 0.4	14-15	-	0.5-0.8	-	0.1-0.2
Ferritic	1.4016	0.08-0.12	16-18	0-0.75	-	-	-
Austenitic	1.4301	0.07	17-19.5	8-10.5	-	-	-
	1.4401	0.07	16-18.5	10-13	2-2.5	-	-
	1.4539	0.02	19-21	24-26	4-5	1.2-2.0	-
Duplex	1.4362	0.03	22-24	3.5-5.5	0.1-0.6	0.1-0.6	-
	1.4462	0.03	21-23	4.5-6.5	2.5-3.5	-	-
Super Austenitic	1.4547	0.02	19.5-20.5	17.5-18.5	6-7	0.5-1.0	-

*Fe, mainly, and other elements (eg Si, Mn, N, P, S) to 100%. Ref. Avesta Sheffield, 1998).

Metallic food contact materials

Stainless steels are important food contact materials in the food and beverage industries where they are, for instance, used for transportation, e.g. in milk trucks; for processing equipment, e.g. in the dairy and chocolate industry, in processing of fruit such as apples, grapes, oranges and tomatoes; for containers such as wine tanks; for brew kettles and beer kegs; for processing of dry food such as cereals, flour and sugar; for utensils such as blenders and bread dough mixers; in slaughter-houses; in processing of fish; for nearly all of the equipment and many of the fittings in big kitchens, such as in restaurants, hospitals, etc. Stainless steels are also important in domestic food contact applications e.g. for electric kettles, cookware and kitchen fittings such as sinks, counters and drains; for bowls, knives, spoons and forks. This extremely wide usage reflects the fact that stainless steels resist corrosion by foods and beverages, and they are readily cleaned, thereby providing hygiene in food preparation and handling. No flavours or discoloration are imparted to foods and beverages in contact with stainless steels.

Migration information

“Stainless steels” are so called because they are resistant to corrosion in conditions under which iron or non-stainless steels would rust or corrode (EUROFER, 1998). The corrosion resistance of stainless steel result from a naturally formed very thin protective surface layer often called a passive film (see section on corrosion, Introduction). Chromium is the essential element for the formation and stabilisation of the passive film (EUROFER, 1998). Increasing the chromium content, from the minimum of 10.5% necessary for “stainless steel”, to 17 or 20% greatly increases the stability of the passive film (EUROFER, 1998). This film, only a few Å thick, forms almost instantaneously on contact with the oxygen in air or water. Agitation or abrasion does not easily break down the film, but rapid self-healing occurs if the film is damaged. Nickel promotes repassivation and molybdenum is very effective in stabilising the film in the presence of chlorides. Hence, these two alloying elements are used in many of the stainless steels used in food contact applications. However, small amounts of the metallic elements in the alloy may migrate into foodstuffs from food preparation and cooking equipment leading to human ingestion, and there is a need to address the question whether such release can cause adverse health effects.

A wide range of stainless steels are highly resistant to corrosion in acetic acid (concentration range 1-20%) at temperatures up to boiling point (Avesta Sheffield Corrosion Handbook, 1994). Similar corrosion resistance is seen in beer, citric acid (to 5%), coffee, fruit juices, wines, lactic acid, milk and various detergents. It is well known that molybdenum improves the corrosion resistance of stainless steels in contact with foods or fluids which contain chloride ion. In Italy, stainless steels must meet certain migration criteria in a variety of media before they can be approved for food contact applications. The list of approved stainless steels includes the standard austenitic grades: 304 (18% Cr, 10% Ni) and 316 (17% Cr, 12% Ni+Mo). In addition, some European Standards (e.g. EN ISO 8442-2) specify the finish quality of the products and their ability to meet test criteria which minimise the likelihood of pitting or crevice corrosion occurring during the normal lifetime of the product.

The migration from stainless steel is generally assumed to be a time-dependent measure of metal transition. However, tests have shown that the migration of nickel from stainless steel decreases time-dependently to a minimum value, which is below 0.1 mg/m² (usually below 0.1 mg/kg foodstuff) for all the brand-new pots examined (Bünig-Pfaue & Strompen; Vrochte et al., 1991).

Preparation of foodstuffs such as rhubarb, sauerkraut and red wine sauce in brand new stainless steel cooking pots may cause chemical surface changes of the stainless steel surface. These changes are to be regarded as the development of a protective layer which reduces further nickel migration (Bünig-Pfaue & Strompen; Vrochte et al., 1991). The release of nickel ions from stainless steel pots is generally less than 0.1 mg/kg (NiDI, 1994). The amount of nickel derived from the utensils in standard portions of various "aggressive" foodstuffs is 0-0.008 mg.

The highest rates of chromium and nickel release from saucepans has been seen from new saucepans on first use (Flint and Packirisamy, 1997). The nickel and chromium release was tested in rhubarb, apricots, lemon marmalade, tomato chutney and boiled potatoes. The release of nickel was approx. 0.2 mg/kg for apricots and rhubarb after the first cooking operation. After the first two cooking operations, the highest nickel release for apricots and rhubarb were reduced to approx. 0.07 mg/kg and 0.01 mg/kg, respectively. Correspondingly, the release of chromium was 0.05 mg/kg and 0.01 mg/kg, respectively.

Studies on the migration of chromium and nickel using cooking utensils made of ferritic and austenitic stainless steel and glass have shown that the migration of nickel and chromium into an average daily diet is negligible compared with the natural contents of these elements in foodstuffs. Furthermore, no significant difference in migration has been noted between these steels and glass.

Safety aspects

- There has been no formal evaluation of stainless steel products used in food contact applications in relation to their potential to give rise to concern for health.
- Numerous studies of corrosion in various media and of uptake of metals by foods cooked in stainless steel pans give rise to no concern for health due to excessive intakes of nickel or chromium from the stainless steels.
- Special grades of stainless steels are available for use in particular applications (e.g. those involving contact with relatively high levels of chloride ions) where particular corrosion resistance characteristics are required.

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APPENDIX I

**METALLIC ELEMENTS FOUND AS
CONTAMINANTS AND IMPURITIES**

Cadmium

Introduction

Cadmium is one of the metallic elements of most concern in the food and environment of man. Cadmium is widely distributed (Codex, 1995). Cadmium occurs in the surface of the Earth in all soils and rocks, including coal, in very low concentrations (<0.1 mg/kg) (ATSDR, 1997, Lind, 1997). Also, zinc ores contain cadmium, which is emitted during the melting of zinc (Friberg et al., 1986). Cadmium is a relatively rare element and current analytical procedures indicate much lower concentrations of the metal in environmental media than did previous measurements due to improved sampling and analytical techniques (WHO, 1992). Phosphate fertilisers and sewage sludge used on agricultural land may be significant sources of cadmium (Friberg et al., 1986). Cadmium can be replaced by other less toxic materials, for instance in batteries.

Main sources of cadmium in the diet

Cadmium is found in most foodstuffs in the range of 0.005-0.1 mg/kg (Friberg et al., 1986). Certain foodstuffs, e.g. mushrooms, kidney and oysters, may contain much higher concentrations (Friberg et al., 1986). The lowest levels of cadmium are found in fruits and beverages (European commission, 1996). Vegetables, cereals and cereal products make the greatest contribution to cadmium intakes. Cigarette smoking has been shown to contribute significant amounts of cadmium to the intake (Friberg et al., 1986).

Metallic food contact materials

Cadmium metal has mainly been used as an anticorrosive, electroplate on steel (Friberg et al., 1986). Cadmium can occur as impurities in zinc galvanised pipes and in solders (Friberg et al., 1986).

Other food contact materials

Cadmium sulphide and cadmium selenide have been used as red, yellow and orange colour pigments in plastics and various types of paint (Friberg et al., 1986). Cadmium stearate was previously used as a stabiliser in plastics (Friberg et al., 1986). Cadmium can also be used as pigments in certain enamels in food contact materials. Leachable cadmium in enamel pottery and glazes may be a source of contamination.

Migration information

The migration information on cadmium is limited. Cadmium, like zinc, loses its lustre in moist air and is rapidly corroded by moist NH_3 and SO_2 . It is readily attacked by most acids, but more slowly than zinc (Beliles, 1994).

Safety aspects

- JECFA (1993) has established a PTWI at 0.007 mg/kg of body weight stating that “the PTWI does not include a safety factor” and that “there is only a relatively small safety margin between exposure in the normal diet and exposure that produces deleterious effects”.

- SCF (1997) endorsed the JECFA PTWI of 0.007 mg/kg b.w. The committee concluded that for a significant part of the population, exposure to cadmium from dietary sources alone is at a level close to the PTWI. Also, the committee could not exclude a carcinogenic risk from dietary exposure to cadmium.
- WHO (1993) has established a guideline value for cadmium in drinking water at 0.003 mg/l.
- The average ingested amount of cadmium in most European countries is 0.01-0.02 mg/day (European Commission, 1996).
- Cadmium is unique among the metals because of its combination of toxicity in low dosages, long biologic half-life (about 30 years in humans), its low rate of excretion from the body, and the fact that it is stored predominantly in the soft tissues (liver and kidney) (Beliles, 1994). The PTWI is based upon kidney damage and the long half-life of cadmium. The effects of cadmium on humans are nephrotoxicity, osteotoxicity, cardiovascular-toxicity and effects on reproduction and development and genotoxicity (European Community, 1996). Kidney damage also occurs as a result of cadmium exposure (Beliles, 1994). Occasional peaks in cadmium intake may cause a drastic increase in fractional absorption of cadmium (Lind, 1997). Ingestion of highly contaminated foodstuffs or drinks results in acute gastrointestinal effects in form of diarrhoea and vomiting (Friberg et al., 1986). About 5% of ingested cadmium is absorbed (Friberg et al., 1986). The speciation of cadmium in foodstuffs may be of importance for the evaluation of the health hazards associated with areas of cadmium contamination or high cadmium intake (WHO, 1992).

The bio-availability of cadmium differs depending on the form of cadmium present. For instance, cadmium of animal origin has been shown to have a lower bio-availability in mice than cadmium of vegetable origin (Lind, 1997). Cooking does not seem to alter the bio-availability of cadmium of animal origin.

Conclusions and recommendations

Use of cadmium in metals and alloys in materials in contact with foodstuffs is unacceptable due to the extremely long half-life and the high toxicity of cadmium.

- Cadmium plated utensils in food processing and preparation is forbidden according to Directive 91/338/EEC.
- Electroplated equipment should be coated.

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Cobalt

Introduction

Cobalt is a rare element, composing about 0.001% of the earth's crust (Beliles, 1994). Cobalt often occurs in association with nickel, silver, lead, copper and iron ores (Elinder and Friberg, 1986). Cobalt is present in the vitamin cobalamin or vitamin B₁₂ (Elinder and Friberg, 1986).

Main sources of cobalt in the diet

Cobalt is normally found in very low concentrations in foodstuffs (approx. 0,01-0,05 mg/kg) (Beliles, 1986) with green leafy vegetables as main contributors (Codex, 1995). Common plants such as lettuce, beets, cabbage, spinach, and sweet potatoes act as sources of dietary cobalt, containing from 0.1 mg/kg to 0.7 mg/kg for spinach on a moisture free basis (Beliles, 1994).

Metallic food contact materials

Cobalt is used for the production of high-strength alloys (Elinder and Friberg, 1986).

Other food contact materials

In the glass and ceramic industries small quantities of cobalt oxide are used to neutralise the yellow tint resulting from the presence of iron in glass, pottery, and enamels. Larger quantities are used to impart a blue colour to these products (Beliles, 1994). Cobalt oxide is used in enamel coatings on steel to improve the adherence of the enamel to the metal (Beliles, 1994).

Migration information

Cobalt is a relatively unreactive metal; it does not oxidise in dry or moist air at ordinary temperatures (Belies, 1994). Cobalt reacts with most acids, but becomes passive in concentrated nitric acid. Cobalt is not attacked by alkalis, either in solution or when fused, but it combines with halogens when heated (Beliles, 1994).

Safety aspects

- JECFA has not evaluated cobalt.
- The estimated intake is 0.2 to 1.8 mg/day (Codex, 1995).
- Cobalt is an essential element. An amount of 5 mg in the body is required for vitamin B₁₂ to avoid pernicious anaemia, a fatal illness. Generally cobalt has a low toxicity (Codex, 1995). Gastrointestinal absorption of soluble cobalt compounds can be estimated to about 25% (Elinder and Friberg, 1986). Cobalt is used in fertilisers, since a low cobalt concentration in soil may cause cobalt deficiency in sheep and cattle. Also, cobalt is used in human medicine in the treatment of certain iron-resistant anemias (Elinder and Friberg, 1986). Even though cobalt is essential to both humans and animals a few cases of poisoning have been seen. Effect on heart, blood pressure, pain in the abdomen, difficulties of breathing and in the worst cases death were seen after intake of cobalt via large amounts of contaminated beer (cobalt used to prevent fermentation) (Elinder and Friberg, 1986).

Conclusions and recommendations

Although there is no specific evaluation of cobalt it seems that the use of cobalt in general causes no problems. Therefore,

- As cobalt is used in alloys, glass and glazing pottery only, which normally do not rise any problem by correct use, no specific recommendation concerning migration is needed.

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Mercury

Introduction

Mercury is among the metals of most concern for human health, especially organic mercury. Mercury in ambient air originates mainly from volcanic activity and industrial activity (Codex, 1995). The burning of fossil fuels, the melting of sulfide ores, cement manufacture and the heating of other materials containing mercury, release about 100 tons of mercury into the global atmosphere each year (Florence and Batley, 1980). Methyl mercury is biosynthesised from inorganic mercury as a consequence of microbial activity (ATSDR, 1997). Methyl mercury is found in foodstuff and in particular in fish and seafood. Much has been done in the last decade to limit or remove the sources of mercury contamination of foodstuff.

Main sources of mercury in the diet

Mercury is found in concentrations ranging from 0.005-0.05 mg/kg in foodstuffs. The main contributor is methyl mercury in fish, which contains up to 2-4 mg/kg. The average level of mercury in fish is 0-0.08 mg/kg (National Food Agency of Denmark, 1995). In fish, the major amount of mercury is methyl mercury (Beliles, 1994; Berlin, 1986). In Commission Decision 93/351 of 19 May 1993 for setting an average limit of 0.5 mg/kg in fish (raised to 1.0 mg/kg in edible parts of certain species) has been laid down.

Metallic food contact materials

No information is available.

Other food contact materials

Sources of mercury may be the chloroalkali industry, the electrical industry, the manufacture of paints, instruments, agrochemicals and other specialist items. Mercury has a propensity to form alloys (amalgams) with almost all other metals except iron (Beliles, 1994). The amalgam used in dental fillings contains tin and silver (and sometimes, gold) dissolved in mercury (Beliles, 1994).

Migration information

No information is available.

Safety aspects

- JECFA has in 1978/1988 established a PTWI at 0.005 mg/kg body weight for mercury, however, with a maximum at 0.0033 mg/kg body weight for methyl mercury. It was, however, stated that this PTWI might not adequately protect pregnant women, i.e. the foetus.
- WHO (1993) has set a guideline value for total mercury in drinking water at 0.001 mg/l.
- The average daily intake of mercury is reported to be between 0.002-0.02 mg, mainly varying with the amount of fish products in the diet (Codex, 1995).
- Mercury, in its metallic form, is unlikely to cause poisoning by ingestion whereas the vapour is toxic. Methyl mercury and ethyl mercury are the most toxic forms of organic mercury (Codex, 1995). The oral absorption of elemental mercury is limited and may be approximately 0.1% (Beliles, 1994), whereas methyl mercury is absorbed 100%. Some

inorganic mercury salts may be better absorbed as well as organic mercury compounds (Beliles, 1994). The toxic properties of mercury vapour are due to mercury accumulation in the brain causing neurological effects, involving an unspecific psychoasthenic and vegetative syndrome (micromercurialism) (Berlin, 1986). At high exposure levels mercurial tremor is seen, accompanied by severe behavioural and personality changes, increased excitability, loss of memory and insomnia (Berlin, 1986). Low concentrations of methylmercury causes cell death and inhibition of cell proliferation in cell cultures, whereas mercury primarily disrupted the plasma membrane (Braeckman et al., 1997). Methyl mercury is listed as one of the six most dangerous chemicals in the environment. Inorganic mercury is classified as a carcinogen. However, there is a lack on data on humans (Beliles, 1994). Mercury and silver interferes with copper distribution. The general population is exposed to methyl mercury primarily through diet (organic mercury) and dental amalgam “fillings” (inorganic mercury) (ATSDR, 1997).

Conclusions and recommendations

- Mercury should not be used in food contact materials.

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APPENDIX II

COMPARISON OF THE INTAKES OF SELECTED

METALS WITH THEIR PTWI

Appendix II

Comparison of the intakes of selected metals with their PTWI

	A	B	C	D	E	F ³
	Mean (mg/day) ¹	Mean (mg/week)	PTWI mg/kg bw/week)	Daily intake as TDI or PMTDI (mg/kg bw/day)	Estim. prov. tol. Weekly intake (mg/ week) ²	Mean intake % of PTWI (%)
Al	6	42	7	-	420	10
C	0.2	1.4	-	-	-	-
Cu	3	21	-	0.5 (PMTDI)	210	10
Fe	15	105	-	0.8 (PMTDI)	336	31
Pb	0.05	0.35	0.025	-	1.5	23
Mn	-	-	-	-	-	-
Ni	0.4	2.8	-	0.005 (TDI)	2.1	>100
Ag	0.007	0.05	-	-	-	-
Sn	4	28	14	-	840	3
Ti	0.8	5.6	-	-	-	-
Zn	17	119	-	1 (PMTDI)	420	28
Be	-	-	-	-	-	-
Cd	0.015	0.105	0.007	-	0.42	25
Co	1	7	-	-	-	-
Hg Methyl- mercury	0.01	0.07	0.005 0.0033	-	0.3 0.2	23

¹ Beliles (1994); Codex (1995).

² Estimated from the daily intake per kg body weight for a 60 kg person.

³ Calculation: $F=B*100/E$

APPENDIX III

NATURAL ELEMENTS'

CONTENT OF FOODSTUFFS

Appendix III

Natural elements' content of foodstuffs

Foodstuff	Al ¹ (mg/kg wet weight)		Cu ² (mg/kg wet weight)		Ni ³ (mg/kg wet weight)		Cr ⁴ (mg/kg wet weight)	
	Mean ± range		Mean ± range ^a		Mean ± range		Mean ± range	
01 BEVERAGES								
Water	0,12	0,08						
Cola	0,11	0,01			0,001			
Coffee	0,11	0,01			0,015			
Tea	4,4	0,08			0,052			
Orange Juice	0,7	0,02			0,015			
Beer	0,5	0,02			0,004			
Wine	0,93	0,01			0,028			
02 STARCHES								
Corn Flakes	0,18	0,01						
Wheat flour			1,5	0,95-2,9	0,135			
Bread, white	2,3	0,02	1,5	0,89-2,2	0,053			
Bread, whole wheat	2,9	0,05			0,087			
Rice	1,4	0,04			0,083 f		0,16 0,007 e	0,19-0,405
Spaghetti	0,4	0,01						
Pasta	6,7	0,6			0,012 g		0,002 e	
Pasta, canned					0,081			
Cookies					1,273			
Biscuits	16,3	0,2			0,243			
03 CHOCOLATE, SUGAR AND PRODUCTS THEREOF CONFECTIONARY PRODUCTS								
Sugar, white	0,05	0,04	2		0,003			
Honey	0,74	0,03	0,5		0,012			
Chocolate pudding	2,33	0,07			0,185			
Cocoa powder			36,4	33-410				
Milk chocolate	6,84	0,08	3					
Doughnuts	12	0,2	1,1		0,178			

Foodstuff	Al ¹ (mg/kg wet weight)		Cu ² (mg/kg wet weight)		Ni ³ (mg/kg wet weight)		Cr ⁴ (mg/kg wet weight)	
	Mean ± range		Mean ± range ^a		Mean ± range		Mean ± range	
04 FRUITS, VEGETABLES AND PRODUCTS THEREOF								
Apples	0,14	0,01	0,25	0,21-0,31	0,042			
Pears			0,81	0,48-2,7	0,133			
Bananas	0,05	0,01	0,95	0,7-1,2	0,078			
Oranges	0,15	0,01						
Citrus fruit					0,062			
Pineapple					0,162			
Grapes					0,01			
Raisins	3,1	0,02			0,074			
Plums, prunes, dried, canned					0,284			
Asparagus	4,4	0,1						
Beans	3,4e	0,1e			0,222 k		0,004-0,04 0,016 e	
Cabbage	0,1	0,01						
Cucumber	0,1	0,01			0,187			
Potatoes	0,7e	0,2e	0,72 and 0,96	0,26-2,2			0,000 3-0,21 0,018 e	
Potato skins					0,982 e			
Potatoes peeled					0,042 e			
Spinach	25,2e	0,2e						
Celery					0,058			
Broccoli					0,081		0,19 0,118 e	
Cabbage, cooked and coleslaw					0,027			
Cauliflower, raw and cooked					0,069			

Foodstuff	Al ¹ (mg/kg wet weight)		Cu ² (mg/kg wet weight)		Ni ³ (mg/kg wet weight)		Cr ⁴ (mg/kg wet weight)	
	Mean ± range		Mean ± range ^a		Mean ± range		Mean ± range	
Beans, raw and canned, cooked								
Carrots			0,4 and 0,61	0,26-0,95	0,056 0,006 l		0,08-1,15 0,004 e	
Peas					0,225 k		0,03	
Lettuce			0,47 and 0,72	0,2-1,4	0,097		0,013-0,17	
Onions					0,06 0,044 e			
Mushrooms					0,045 0,152 j			
Tomatoes	0,12	0,01	0,36 and 0,55	0,29-1,1	0,036			
05 FATS AND OILS								
Corn oil	0,02	0,01						
Cooking fats and salad oils					0,045			
Butter	0,25	0,04			0,017			
Peanut butter & Peanuts					1,467			
Margarine	0,19	0,03			0,185			
06 ANIMAL PRODUCTS AND EGGS								
Fish	0,01	0,01					0,025-0,2 0,007 e	
Marine fish					0,211 e			
Freshwater fish					0,047 e			
Fish, canned					0,101			
Shellfish, fresh or frozen					0,118			

Foodstuff	Al ¹ (mg/kg wet weight)		Cu ² (mg/kg wet weight)		Ni ³ (mg/kg wet weight)		Cr ⁴ (mg/kg wet weight)	
	Mean	± range	Mean	± range ^a	Mean	± range	Mean	± range
Cod			0,19	0,12-0,28				
Tuna			0,64	0,48-0,8				
Beef	0,4	0,02	0,8 and 1,1	0,74-1,6	0,047 - 2,521			
Pork			0,9 and 1,4	0,44-7,22	0,702 e1,009			
Lamb			1,6	1,1-1,9				
Veal					0,067 e			
Salami	1,1	0,03						
Ham	0,5	0,02						
Liver beef			39	8,8-87				
Liver pork			9	0,9-29				
Liver lamb			97	28-195				
Kidney beef			3,7	2,8-4,2				
Kidney pork			6,1	2,9-15				
Meat							0,02-0,169 0,024 e	0,022 e-0,026 e
Chicken	0,7	0,03			0,283 e		0,09-0,15 0,12e	
Turkey	0,1	0,01						
Sardines in tomato sauce	0,7	0,2						
Mackerel in oil	0,4	0,2						
Eggs	0,1e	0,01e			0,007			

Foodstuff	Al ¹ (mg/kg wet weight)		Cu ² (mg/kg wet weight)		Ni ³ (mg/kg wet weight)		Cr ⁴ (mg/kg wet weight)	
	Mean ± range		Mean ± range ^a		Mean ± range		Mean ± range	
07 MILK PRODUCTS								
Milk	0,06	0,01	0,06	Trace-0,14	0,009			
Yoghurt	1,1	0,1			0,014			
Cheese	0,2b	0,03			0,066 0,019 h			
Cheese, processed	300	4			0,100 d			
08 MISCELLANEOUS								
Baking powder	2300							
Pickles	1,9	0,2						
Mayonnaise	0,08	0,01						
Tomato sauce	2,8	0,6						
Ice cream	2,1c	0,1			0,323			
Pepper	143							
Oregano	600							
Basil	3100							
Cinnamon	82							

a : Range = Minimum-Maximum

b : Cheddar

c : Chocolate

d : Processed cheddar

e : Cooked or boiled

f : Rice cereal cooked

g : Plain, cooked

h : Cottage cheese

i : Cooked, canned

j : Canned

k : Raw and canned, cooked

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