National Institute for Public Health
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Ministry of Health, Welfare and Sport

Heavy metals in packaging

A literature survey

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Colofon

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Contents

Summary

The use of the heavy metals cadmium, mercury, chromium and lead in packaging is forbidden internationally for some years because these substances are harmful to the environment. In 2002 the Dutch national Inspectorate for the Environment determined the presence of heavy metals in packaging for consumer products.
A literature survey was commissioned by the Dutch national Inspectorate for the Environment. Objective was to gather information about actions and checks in other countries on the presence of heavy metals in packaging. gain knowledge about the current situation worldwide.
In this literature survey from the RIVM it appears that only in the U.S.A. two investigations were conducted that are comparable to the Dutch study.
According to two American studies the same products have the same bad results as in the Netherlands: plastic bags and transparent packagings.
Apart from these some smaller scale investigations on specific aspects of packaging were reported, such as on crates and on ink from recycled paper.
It is possible that other actions exist but that the results are not published in open literature.
Furthermore, it appeared that governments put a lot of effort in informing producers and importers about the packaging regulations. No data were found if inspectorates enforce these regulations.

1 Introduction

1.1 Background of the literature survey

In the Netherlands the Paper and Cardboard Packaging (Management) Decree (Besluit beheer verpakkingen en papier en karton) contains the requirements that apply to packaging. This decree complies with European directive 94/62 EC. Various requirements and obligations related to the production of packaging apply. Requirements are set especially with regard to manufacture, product re-use and recycling of packaging. Several obligations follow from these requirements. One of the requirements of this regulatory framework is that the heavy metals content shall be reduced and finally be phased out gradually altogether. In the Dutch regulatory framework this is worded as follows: "The total concentration of lead, cadmium, mercury, hexavalent chromium or their compounds in packaging or a packaging component shall not exceed 100 ppm mass units".
As from 1st January 1998 the market is open only to packaging that complies with the essential requirements. The European directive states that packaging is supposed to comply with the essential requirements when it is in agreement with the harmonised standards.

In 2002 VROM Inspection asked RIVM to perform research on the state of affairs as regards heavy metals in packaging (Mennen et al., 2002). Major research was performed, consisting of two parts. The first part was a literature survey with the objective to make an inventory of the packaging chain, the amounts of packaging in circulation and the heavy metals contents in various types of packaging materials. The second part was a pilot study on heavy metals in plastic packaging in the Netherlands to find a good procedure for the enforcement of the regulatory framework on packaging and packaging waste. This research covered 357 packagings of which 7-8% appeared not to comply with the requirements. The method used consisted of screening with a non-destructive portable XRF, followed by an accurate chemical analysis of questionable packaging

In 2010 VROM Inspection carried out a chain project on plastics (packaging) waste - *Kunststof (verpakkings) afval* – that aims at reducing the risks of the amount of packaging, limiting the danger of packaging in the waste phase, stimulating re-use of materials and preventing the illegal disposal of packaging waste abroad. Realisation of the chain project is implemented in four sub-projects, one of which is the sub-project "*heavy metals in packaging*".
Within the scope of this project, VROM Inspection requests RIVM, on the basis of a literature survey, to present a current picture of the facts regarding heavy metals in packaging materials. Has any new research been carried out in the field of heavy metals in packaging? What materials contain heavy metals, who is in charge of inspections and how is the inspection system set up in various countries?

This report describes the findings of a literature survey on research projects on heavy metals in packaging since 2002.

1.2 Objective

VROM Inspection intends to reduce the use of heavy metals as additives in packaging to limit the risks of harmful effects on health, environment and labour conditions in the handling of packaging in the production, transport, use and waste phases.
For that purpose RIVM performs a literature survey on available (recent) publications and refers to the information in the network. On the basis of the information investigated, RIVM provides a current view of the presence of heavy metals in packaging and of the types of packaging that constitute a relatively large risk of exceeding the packaging decree standard.

2 Regulatory framework

2.1 International framework

The European Commission has issued several directives on packaging. Directive 94/62 EC Packaging and Packaging waste and the amending Directive 2004/12/EC are currently in force.
Annex II to Directive 94/62/EC on packaging and packaging waste determines the essential requirements which all packaging on the market within the European Community shall comply with.

These essential requirements can be summarised as follows:
- The packaging volume and weight shall be limited to the minimum amount necessary for the required safety, hygiene and acceptance for the packed product.
- The harmful and other dangerous substances and materials as components of the packaging shall be minimised to prevent any adverse effects
- The packaging shall be suitable for recovery in the form of recycling of materials, energy recovery, composting or re-use.

Harmonised standards have been set up by CEN, the European Committee for Standardization and accepted in the Netherlands and published by NEN under the title:

> NEN-EN 13428:2004 NL Verpakking - Specifieke eisen voor fabricage and samenstelling - Preventie door reductie aan de bron. [Packaging - Requirements specific to manufacturing and composition - Prevention by source reduction]

This document specifies a procedure for the assessment of packaging to guarantee that the weight and/or volume of the material component is minimal, simultaneously maintaining:
1) the functionality in the entire supply and consumption chain,
2) the safety and hygiene for both product and user/consumer, and
3) the acceptability of the packed product for the user/consumer.

This document also specifies the method and procedure for determining the presence of the four heavy metals stated in article 11 of Directive 94/62/EC on packaging and packaging waste, and for determining the presence of and minimising any dangerous substances and preparations present in the packaging that are likely to be released in the environment due to waste management operations.

2.2 Presence and prevention of heavy metals in packaging

With the Paper and Cardboard Packaging (Management) Decree (Besluit beheer verpakkingen en papier en karton) the Dutch regulatory framework imposes on producers and importers the obligation to continuously take preventive measures to meet the essential requirements as formulated in the European directive. As regards the aspect of harmful substances this means that the producer must look for adequate substitutes for heavy metals and their compounds in packaging that exceeds the standard. In the case of re-use of packaging materials which contain heavy metal compounds or even exceed the

limit values, the producer shall closely monitor that the standard is not exceeded in the production of new packaging. Re-use (recycling) of packaging materials carries the risk of diffuse heavy metals distribution in new product packaging materials. This may be expected especially in open chains that are not inspected. More in general the producer must aim at minimising the contents of heavy metals and their compounds. This can be achieved by using substitute additives in packaging materials, or alternative packaging materials, using different designs and better manufacturing technologies.

The past has seen several examples of packaging in which heavy metals and their compounds were used (on a large scale):

- Leaded glass.
- Coloured glass. *All four metals as stated in the regulatory framework can be involved.*
- Coloured plastics. *Both lead (chromate) and cadmium salts produce colours that vary from red to orange and yellow.*
- Thermal and UV stabilisers in plastics such as PVC. *This applies to cadmium and lead compounds, which are now banned.*
- Tin cans with lead solder.
- Inks. *This refers to the use of heavy metals in compounds for pigments, and also to heavy metals serving as a natural background in oils.*

Most of these examples are no longer allowed.

3 Literature survey on heavy metals in packaging

3.1 Procedure

RIVM has access to various scientific literature databases. Databases can be searched worldwide by means of software packages such as Scopus and Picarta. Scopus is a large Elsevier database of abstracts, peer-reviewed literature and web sources. These are updated on a daily basis by all kinds of international libraries. PiCarta allows RIVM access to the joint catalogue of Dutch libraries with books and papers in trade journals. Scientific WebPlus is a database of Thomson Reuters that searches the internet on a more scientific approach than standard search engines such as Google.
Retrieving scientific research results is easier than retrieving enforcement actions by government bodies. Not all government bodies will issue scientific reports on enforcement results. For that reason, internet queries at other European enforcement authorities were made.

Also the RIVM network was searched for knowledge on heavy metals in packaging.

The various databases were queried for "heavy metals" and "packaging". This was mostly done in English, but also in Dutch, French, German and Spanish. Finally, the literature survey highlights four areas of special attention: enforcement, food safety, analysis methods and re-use.

3.2 Enforcement

In the European countries several government bodies are charged with the enforcement of limit values for heavy metals in packaging materials. The regulatory framework appears on websites in a variety of languages. This does not make it clear whether a country complies with the regulatory framework. The European Parliament has approved the regulatory framework on a number of conditions. The European Commission is expected to closely monitor the effects of the regulatory framework. This is done in several ways. Finally, the Commission itself reports to the European Parliament. Various institutions have made reports to the European Commission. For countries outside Europe a fair amount of US literature has been found.

The Netherlands
In 2003, 2005, 2007 and 2008 VROM Inspection, the body in charge of supervision and enforcement in the Netherlands, performed investigations on packaging and heavy metals in packaging materials. In 2003 some wholesalers and distribution centres were visited. Only two violations were reported. The 2005 inspection was in response to a notification from the Belgian authorities on printed bread bags. However, these were not found in the Netherlands. In 2007 VROM Inspection together with the VWA (the Dutch Food and Consumer Product Safety Authority) performed screenings on food packaging. No exceedances of heavy metals were observed here. In 2008, on the occasion of the European Football Championship, a screening of orange-coloured products was carried out. It is difficult to find out whether this type of screenings are also carried out in other countries. No relevant reports were found in public literature sources.

Other European countries
In Belgium the Federal Public Service for Health, Food Chain and Environment is in charge of the enforcement of the regulatory framework. On the website, the Federal Environmental Inspection informs that they are checking for heavy metals in packaging. No results of these inspections were found on this site (http://www.health.belgium.be/eportal).

In the United Kingdom the Department for Business, Enterprise and Regulatory Reform (BERR) manages the Packaging (Essential Requirements) Regulations. Responsible for enforcement are the departments of local authorities. The situation in France and Germany is comparable. Member states are responsible for enforcement. No literature was found that provides insight into the actual situation of enforcement by member states.

In France the Conseil National d'embellage is a joint institution of government, producers and other parties interested in the packaging sector. The website shows packagings that have been largely improved. In general improvements are weight reductions, but also materials are improved. Nothing was found on heavy metals.

EU
The European Commission initiated several screenings to assess the effects of the regulatory framework. One of these was performed by GHK (2006) on the financial effects of the regulations. The complexity of the market as well as the absence of a good description of the market prior to implementation makes it impossible to show these effects.

Arcadis investigated the compliance with the essential requirements in the regulatory framework. The framework of this investigation was much broader than that of the research that specifically dealt with the heavy metals and their compounds in packaging. No specific results are reported for the contents of metals in packaging. (Arcadis , 2009)

United States
Nineteen states in the USA have legislation and regulations that prohibit the sale or distribution of packaging with (intentionally added) cadmium, lead, mercury or hexavalent chromium. Should these metals appear to be present, the total concentration in the product shall not exceed 100 ppm. US legislation also states that this is not punishable unless the metals have been added on purpose. As to these two aspects to some extent legislation differs from that in Europe. The Toxics in Packaging Clearinghouse (TPCH) was established by the Coalition of Northeastern Governors (CONEG) in 1992 to assist the states to implement packaging legislation. TPCH investigates packaging on behalf of the nineteen states, financed by the US Environmental Protection Agency (EPA). The first report was published in 2007 and describes the test results for 355 packagings between October 2005 and February 2006. The screenings were continued in 2008 which resulted in a second report in June 2009. This contains the results of 409 packaging tests.

The first report (2007) describes the tests of 355 packagings by the same method as used by RIVM several years earlier. The non-destructive test with a handheld XRF was used to measure all packagings.

In the 355 packagings the limit value of 100 ppm of one of the elements stated was exceeded 57 times. This screening does not serve as a basis to assess

whether the packaging complies with the law. For that it must also be demonstrated that the elements were applied on purpose and that the total of elements does not exceed a value of 100 ppm.

Two types of packaging are responsible for the majority of the exceedances:

1. Flexible transparent PVC packagings: Involved were 41 flexible PVC packagings out of a total of 57 failures. In 24 packaging samples the cadmium content exceeded the limit value of 100 ppm. This type of packaging was especially found with goods such as textiles, cosmetics, toys and pet products
2. Ink and pigments on plastic shopping bags.

The highest lead concentration was found in a plastic bag. It contained approx. 1 weight % of lead (or rather 10,000 mg per kg = 10,000 ppm-m). This high concentration can be explained by the amount of pigment and the relatively low weight of the plastic bag.

TPCH cautioned the companies because their packaging materials failed to comply. Most of the companies responded in the negative. They could present analysis results that stated that the products did comply. The report states that one of the explanations is that companies that put product packaging on the market do not receive adequate information when packaging production methods change, which is not uncommon. Another explanation is that unsuitable tests have been performed. Screenings performed in the food industry and in the toy industry often aim at monitoring the leaching of metals and heavy metals from products. The results of these tests are not indicative of the content of heavy metals in the product packaging.

TCPH's measurements of 2008 were set up somewhat differently. Special emphasis was put on the sectors that had poor results in the 2006 screenings, and products were included that were poorly represented in the first test. In this approach TCPH intentionally did not aim at achieving a representative random check.

Within those two years there seem to have been a few improvements. TPCH supposes that producers and/or distributors have become more aware of the regulatory framework thanks to the previous attention that their measurements had obtained.

Again the two product groups - the imported flexible PVC packaging and the inks and pigments on plastic bags – achieved poor screening results. In addition, solder in electronics scored very poorly. TPCH screened 409 packaging samples, resulting in 628 packaging components. This time 58 products were rejected.

No excess values were found in paper, but they were present in ink on paper. Mainly chromium was found there. However, the XRF cannot distinguish between Cr III and Cr VI. Furthermore, the XRF demonstrated a high mercury concentration in ink on plastic packaging. The largest exceedance was found in lead solder in an electronic circuit. It is not described, how this was used as a packaging component. Moreover, it is remarkable that half the samples of flexible PVC packaging (37 out of 71) demonstrate that a limit value is exceeded, in all cases of cadmium, and in some instances of both cadmium and lead.

3.3 Food safety

For quite a long time the food industry has been working on the chemical composition of packaging materials. This industry has to deal with additional regulations that apply to food safety. For many years tests have been performed on the migration of all kinds of substances, including heavy metals. The industry is aware that packaging must protect food, and consequently inks are hardly applied to the inside. There is less awareness of the fact that inks on the outside can also migrate to the food inside through cracks, fractures or diffusion (Ki-Cheol Kim., 2008). There are several tests to determine the leaching of heavy metals and their compounds to food products.

Ki-Cheol Kim. (2008) determined the concentrations of heavy metals in candy packaging. In ten out of 92 packaging samples they found lead in concentrations between 100 and 6,400 mg/kg. This comes from the inks on the packaging with very colourful greens and yellows. Where the lead concentrations are high, so is the chromium concentration (137 to 1,430 mg/kg). Chromium has been identified as hexavalent chromium.

3.4 Analysis methods

The analytical methods to determine heavy metal concentrations in packaging are explained and described in the literature. This was also a major component in the 2002 RIVM report. Many types of packaging are on the market, and the large matrix differences also require more methods to achieve the correct value.

Analysing packaging for the presence of heavy metals is usual in the food industry. The analysis of packaging of other products has only been developed the last decade. The laboratories carried out analyses themselves. In 2000 a standard was issued in the Netherlands: NPR CR 13695-1:2000. Items described in this standard include testing and analysing methods for determining the content and leaching of heavy metals in packaging and packaging components. Three method categories can be distinguished:

- methods for quality inspection for use by the industrial sector,
- methods for use by laboratories not linked with the industry (e.g. inspection and screening laboratories), and
- leaching methods.

For each packaging material the annexes in the standard provide testing and analytical methods to determine heavy metals in packaging samples. Chapter 11 of the standard states that there is a need to standardise the methods. This refers to sample preparation and the testing of statistically representative packaging samples, sampling methods for individual packaging units, sample preparation and testing of samples for emission and leaching assessment of heavy metals from packaging materials and the development of reference materials. The analytical methods recommended are distinguished especially to sample preparation (or the absence of it) and the analytical technology.

There is a non-destructive XRF method for performing the analysis without sample preparation that could result in damage to the integrity of the packaging to be tested. The big advantage is that the composition of the total contents of a large number of elements is determined in a very short time (approx. 15 min). Performance restrictions appear in systematic and accidental deviations. These cannot only be explained by the selection of the analytical technique but also by

the degree of homogeneity (or heterogeneity) of the packaging material and preparation method to allow for an optimum analysis of the samples. For instance, if the product is covered with a thin layer of metallic paint, the metal content can be overestimated as the XRF will detect this thin layer. In 2006 and 2008 TPCH used an analytical method using this technique (see Chapter 3.2). TPCH describes some EPA methods with which a packaging sample is fully destructed to release the metals. That way much higher exceedances are detected.

On behalf of the Korean paper and pulp industry Jo and Jeong (2007) investigated several methods to determine heavy metals in packaging paper. They investigated extraction, migration and destruction methods. The destruction method resulted in the highest measuring values for lead and chromium. The other elements remained below the detection limit.

Guadagnio (2001) describes the development of an analytical method to measure the heavy metal content in glass. There have been several major research projects on lead, cadmium and mercury, but hexavalent chromium is a difficult substance. The 2001 study describes how hexavalent chromium can be released to enable analysis.

Researchers in Argentina discovered an accurate method to determine cadmium when screening food packaging. The reason for this is that food packaging has a long cycle and that even incineration and dumping cause much environmental damage. In the sample preparation the new analytical method includes a pre-concentration step. The resultant test solution is then analysed with a (rapid) AAS technique.

3.5 Re-use

Paper
No heavy metals are included in paper to be used as packaging material. But printing with ink causes low concentrations on the packaging. Paper recycling may cause the heavy metals concentration to accumulate over the years. The heavy metals in ink are present in low concentrations but if the ink is not removed, demonstrable levels can occur.
Cieplinski (2004) tested Polish paper packaging samples for the four heavy metals. The concentrations in recycled paper gradually increase compared with paper made of virgin pulp. The researchers ascribe this to the inking applied to used paper. In 100 samples screened by Cieplinski the concentrations did not exceed 30 ppm (where 100 ppm is allowed in Poland).

In Spain, too, recycled paper was studied. AIDIMA, the Furniture, Wood and Packaging Technology Institute, tested 63 papers intended to be used as packaging materials. The chemical analysis of heavy metals was not the main objective of the project. The paper was screened for a wide range of substances. The tests used (EN 12497 and EN 12498) are validated for packaging materials that can be in contact with food. The methods start from the chemical analysis of metals in an aqueous solution. This might provide hardly any information on the contents of heavy metals in the paper as a whole. None of the paper samples contained cadmium above the detection limit. In several samples mercury was found, and this content averaged 0.48 ppm.

Plastic crates
The regulatory framework for heavy metals in packaging makes an exception for crates and pallets (derogation for plastic crates and plastic pallets). Crates and pallets contain high concentrations of heavy metals but as they can be re-used for many years, their use is still allowed. For crates it must be reported that they are actually returned, to ensure a closed cycle. A condition was that 20% new material be used in case of recycling. This postponement was in force till March 2009.

On behalf of the European Commission BIO Intelligence Service investigated the situation and reported in September 2008. About 33% of the 1.5 million drink crates in Europe still contained heavy metals above the limit value of 100 ppm. BIO Intelligence Service recommends the European Commission to prolong the exception for crates and pallets as the environmental damage is not large. If the crates are banned, this would result in a large polluting waste stream.

4 Conclusion

Since 2002 only a few screenings on heavy metals in packaging have been reported. Only a report on screenings by TPCH presents a status of the situation in the USA. As these screenings have been performed for several years in succession, they provide a clear image and a trend.

In 2006 TPCH found 57 exceedances of the limit value of 100 ppm of one of the elements described in 355 packaging samples. The 2008 screening more specifically covered product groups that had scored poorly in 2006. 58 products or components of products in 409 packaging samples were rejected. Like in the RIVM study of 2002 the flexible transparent PVC packagings and the ink on carrier bags score badly.

These screenings tend to remind producers or importers of the regulatory framework. In two years' time this attention has resulted in improvements in the USA.

A major risk still is that the packaging material or its producer changes in the course of time, so that the composition also changes.

This type of screenings has not been carried out in other countries, or at least no such results have been made public.

Food safety
In the literature survey only one article was found on the composition of heavy metals in candy packaging. In that article the researchers explain that lead and chromium are the critical heavy metals. The articles indicate that the chromium was demonstrated to be Cr VI. Unfortunately it has not been clearly stated what analytical methods were used here. At RIVM it is a known fact that this analysis is very difficult to make and therefore requires much expertise. Determining the contents of Cr III and total chromium, on the other hand, is much easier to be carried out.

Analytical methods
It is not easy to standardise the sample preparation because of the diversity of packagings. The analysis that follows, strongly depends on that. By using an XRF to perform a screening, an inspector can view a large number of products and select for final analysis.

Re-use
The re-use of materials can incur a risk as harmful substances can accumulate. Research has shown that the mercury content in recycled paper tends to increase gradually.

In several countries there are many institutions that represent packaging producers. These institutions try to optimally inform producers on developments in the regulatory framework. Heavy metals in packaging is only a minor aspect then. It is one of many mandatory requirements. Compliance with the essential requirements is a continuous process in which packaging is made lighter, better processable and less harmful to the environment.

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