# Literature report on food packaging materials and their potential impact on human health

by

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## 1. Introduction

The issue of assessment of health risks of food packaging materials (FPMs) represents an ongoing challenge. This is due to the fact that FPMs have the potential for release and subsequent transfer of components into the food. This transfer then can lead to an exposure of the consumer to those components and/or their reaction products. The following article is aimed at presenting and discussing the major facts and perspectives related to this issue also comparing the properties of a broad spectrum of FPM with respect to food safety.

## 2. FPMs and their constituents

Food is packed into a large variety of containers made from a number of different materials and combinations thereof. These have to fulfill several criteria mainly in order to preserve the food, extend its shelve-life and maintain its quality with respect to freshness, taste, flavor, color etc. A major role of FPMs is the avoidance of risks related to microbial or chemical degradation of the food, i.e. unwanted events, which may imply serious health risks.

In addition, packaging of food provides a universal frame for the display of written information, pictures and images about the contents of the package, which have both the function to attract and inform the consumer.

The functions, which a FPM has to fulfill are, therefore, manifold. A major requirement is a reliable barrier function against microorganisms, spores and chemicals. The latter include both compounds which can enter the food and cause a deterioration of quality such as oxygen or strange odor or compounds which should not leave the food such as water, valuable flavor constituents etc.

Furthermore, the FPM should be solid, stable, convenient and consumer-friendly in various aspects, which cannot be presented here in detail.

Plastic polymers of various compositions can fulfill many of these functions in a more or less acceptable way. A major drawback of plastic FPMs, however, is that they require additives to guarantee certain properties required for their function. These include plastifiers to provide sufficient plasticity, antioxidants to protect from degradation by atmospheric oxygen, light protectants to decrease UV-light dependent degradation, colors to generate the intended appearance of the package, printing inks to apply written and graphic information, ornaments etc. Furthermore, the nature of the polymerization process makes it unavoidable that the plastic FPMs contain residues of mono- and oligomers of the starting material(s) as well as additives required for the polymerization and maturation process of the polymer such as catalysts, cross-linkers, polymerization modifiers, stopping components etc.

A further alternative for FPMs is paper and cardboard. These materials mainly originate from wood, which is treated in various ways. Although paper and cardboard including recycling products are widely considered to represent 'natural' FPMs, the manufacturing process of these materials may require the use of a broad spectrum of chemicals. These include preservatives protecting the FPM from degradation by microorganisms, plastic polymer coatings to improve the normally weak barrier function of paper, printing inks and colors, UV protectants, and chemicals used in the pulp and paper production.

Since non-coated paper and cardboard is a relatively porous material, aqueous or oily liquids (from the food) may have access to the body of the material eventually extracting those chemicals from the FPM. The use of recycled paper and cardboard for the production of FPMs is another problematic issue because of chemicals already present in the recycled materials.

The third large group of FPMs is metals. There, iron-based can bodies are in use but usually have to be coated inside with polymers to avoid direct contact with the food. Corrosion by high-salt or acidic food items is a major issue, which precludes direct contact between food and metals to be feasible. A major exception is stainless steel, which, however, cannot be used for most FPM purposes because of its extraordinary high price.  Aluminum cans have to be covered with polymers as well since aluminum also is a quite corrosion-prone metal being rather unstable when coming into contact with many foods.

The fourth and best solution in terms of food safety is glass. Glass is also made from natural materials but  contrary to all other FPMs it does not require any plastic layer to protect the food. This fact makes sure that no organic matter is present in glass and thus cannot migrate into the food. Also the components of glass, i.e. sodium silicates are completely health-friendly and inert, i.e., they are toxicologically irrelevant.

## 3. Substances migrating from FPM into food

Various methods were established in order to determine migration into foods. The levels of exposure usually are minor, however, a widespread and, in many instances, frequent or long-term exposure of consumers warrants a particular interest of toxicologist in these compounds.

Substances migrating from FPMs can be subdivided into no-intentionally added substances (NIAS) and intentionally added substances (IAS) or migrants originating thereof.

IAS often are directly derived from FPMs, i.e., they are identical to the FPM (metals etc.) or represent minor constituents used or are derived from the production process of the FPM such as plastic monomers, plastifiers, dyes, antioxidants etc. NIAS in most cases are compounds, which have not been added intentionally to the FPM during the manufacturing process of the FPM or have been added to a portion of the FPM not thought to come into contact with the food. Migration of components into foods has been identified as a major route of human exposure to FPMs and/or their components (Munro et al., 2002).

Table 1 provides a non-comprehensive list of IAS (intentionally added substances) and NIAS (non-intentionally added substances) migrating from FPMs.

Table 1. Overview over substances migrating from FPM

| Type | class of substance | substance | FPM/use |
|---|---|---|---|
| IAS | plastic monomers | vinyl chloride | PVCs |
| | | acrylamide | polyacrylamides |
| | | caprolactam, | polyamide |
| | | 6-aminohexanoic acid | polyamides |
| | | p-hydroxybenzoic acid | polyesters |
| | | 2-hydroxy-6-naphthoic acid | polyesters |
| | metals | aluminum | aluminum foil |
| | | plastifiers, monomers etc. | plastic polymers, coated aluminium cans, coated paper/cardboard |
| | dyes | | paper/ cardboard |
| | antioxidants | | plastic polymers |
| | plastifiers | bisphenol A, phthalates | plastic polymers |
| | photo-initiators | 2-isopropylthioxanthone | paper/ cardboard |
| | water/fat repellents | perfluorinated acids etc. | paper/ cardboard |
| NIAS | mineral oils | MOSH/MOAH | recycled paper/cardboard |

## 3.1. Plastic polymers

During the manufacturing process of plastic polymers, polymerization is incomplete. Therefore, mono- and oligomers frequently are present in the FPM and can migrate into the food, e.g., EU legislation lists hundreds of chemicals' possible migration from plastic polymers into food (Bradley et al., 2009). A prominent example is acrylamide, a rodent carcinogen and neurotoxic agent in many species including humans. Acrylamide is required for the production of polyacrylamide polymers, which may also be used in FPMs (Krska et al., 2012). Other examples of monomers migrating into food are styrene, vinylchloride etc.. Although the levels migrating into food items under standard conditions are regulated and controlled, a certain degree of migration is virtually unavoidable.

A relatively large number of chemicals are intentionally added to the plastic polymers and may eventually leach into the food (Muncke, 2011). An important group of materials, which are intentionally added during the manufacturing of plastic polymers are plastifiers. Most notably, bisphenol A, a widely used plastifier, has been accused to act as a so-called 'endocrine disruptor', i.e., a synthetic chemical which can affect functions of the endocrine system pivotal for development, reproduction and many other vital functions of the organism (Hunt et al., 2003). The actual risk arising from bisphenol A exposure migrating from FPMs into food is widely considered among most toxicologists (EFSA, 2010; Hengstler et al., 2011) and regulatory bodies to be of minor relevance. However, further research is required to elucidate this issue. Another family of widely used plastifiers is the group of phthalates (Guart et al., 2014). They were also accused to affect endocrine functions and to act as liver tumor promoters, at least in rodents. The current risk assessments for phthalates also consider the actual risk for human health as marginal, however, express the need for further research in this field.

In addition to monomers and plastifiers, plastic polymers usually may contain other types of chemicals namely residues of polymerization aids, catalysts, UV-protectants, antioxidants etc. which may also migrate into foods. Less is known about the actual levels and toxicological relevance of those compounds, although the actual risk associated with such migration is widely considered as acceptable.

## 3.2. Paper and cardboard

Paper and cardboard used as FPMs usually are coated with plastic polymers since they have weak barrier functions in order to avoid the transfer of chemical compounds between the food and the outside world. Therefore, many paper/cardboard-containing FPMs bear the same problems as the plastic polymers (Gärtner et al., 2009). Similar conclusions can be drawn for adhesives used for gluing of paper/cardboard. The latter also contain plastic polymer-like materials in addition to solvents, many of them being of organic nature. Furthermore, polyfluorinated acids and related compounds are used for coating of paper to provide resistance to oil and moisture (Zafeiraki et al., 2014).

Recently, the increasing use of recycled paper/cardboard as the only or partial constituent of FPMs has led to special concerns. This is due to the contamination of recycled paper with a variety of chemicals, mostly derived from printing inks. Likewise, mineral oils are frequently present in recycled paper/cardboard and, due to their lipophilicity and persistence, are easily found in the foods items (Lorenzini et al., 2013). Even in the absence of a direct contact between the food and the FPM, transfer from the recycled cardboard via the gas phase into the food may occur, making the use as a FPM more problematic. Printing ink on paper/cardboard can also be as source of food contamination when non-recycled material is used for manufacturing of FPM. This is due to a variety of constituents such as the photo-initiator ITX (2-isopropylthioxanthone; Rothenbacher et al., 2007).

### 3.3. Metals

The use of a variety of relatively toxic metals such as lead or zinc as/in FPMs has been banned for food containers. Currently, iron/steel-based cans are mostly coated with plastic polymers to avoid corrosion of the metal by food constituents or transfer of metal ions into the food. The latter may affect flavor, color and other quality features of the food in a dramatic way and thus have to be avoided. Aluminum is widely used for the manufacturing of cans for beverages. The relatively reactive nature of aluminum makes it necessary to coat the metal with plastic polymer films, also to avoid corrosion/reaction with the food. Thus the problems eventually occurring from migration of constituents of plastic polymers into food also fully apply to steel and aluminum cans (Cooper et al., 2011).

### 3.4. Glass

Glass is a FPM entirely made from natural raw materials, which are toxicologically inert. The major constituents, i.e. sodium/potassium silicates are non-toxic and chemically highly inert. The transfer of silicates and cations into food is marginal and even if it occurs, is toxicologically irrelevant, since the cations usually present are non-toxic. Virtually no traces of problematic migrants originating from the glass are found in glass-bottled food products (Hayashi et al., 2011).

Cases of concern related to migration of chemicals such as 2-ethylhexanoic acid into food have been associated to glass-made FPMs only, if these were combined with other materials, i.e. in metal lids. The problems of polymers/adhesives used in lids have been solved, however, by the use of alternative processes in their production (Elss et al., 2004).

## 4. Summary and conclusions

In summary food packing has to fulfill a broad spectrum of requirements all being related to the preservation of food quality and the proper presentation and handling of the food item.

With respect to preservation of food quality an effective barrier function is mandatory preventing the transfer from/into the food related to its surrounding/environment. For this purpose, a number of FPMs are suitable including glass, metals, and plastic polymers while paper/cardboard, when used as the only component, cannot fulfill this task in a sufficient way. Among the materials used as barrier, glass is the most effective one representing a virtually complete barrier around the food, which prevents any loss of quality due to penetration or leakage of compounds.

Another important aspect in evaluating the role of a FPMs for food safety is the issue of transfer of FPM-borne compounds into the food. Here, plastic polymers, metals and paper/cardboard have been shown in the past to be an important source for unwanted chemicals in food. These occur via migration of mostly intentionally added constituents or the FPM material itself (metals) into the food thus eventually affecting its quality. Although the risk of exposure towards food contaminated with such compounds is considered as acceptable, more research is needed to clarify this issue scientifically.

Irrespective of these problems, it is evident that glass due to its inert nature and completely non-toxic constituents represents a 100% safe, ideal FPM with respect to consumer's health and food safety.

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