Environmental Hormones in Food Packaging: Migration into Food and the Environment

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May 2009

Endocrine disrupters, or environmental hormones, are compounds that can interfere with natural hormones and thus negatively affect health. The most prominent and extensively tested endocrine disrupter is bisphenol A (vom Saal et al. 2007), where a vast amount of research in animals (*in vivo*) and cells in test tubes (*in vitro*) has been conducted. Bisphenol A's ability to interfere with the natural hormone systems is well studied.

Now, other food-packaging associated compounds are increasingly being tested by scientists who are interested in their hormone disrupting properties. More than 50 known or suspected endocrine disrupters currently are legally used in food packaging materials (Muncke 2009). These substances have been authorized by food safety agencies in the US (FDA, Food and Drug Administration) and/or EU (EFSA, European Food Safety Authority). Authorization is based on toxicological testing that mainly targets carcinogens but does not explicitly include hormone mimicking toxic mechanisms.

Only some known endocrine disrupters leaching from packaging into food have been studied to date, including:

- OPP, a biocide used in beverage cans. It has been detected in canned beers at levels ranging from >0.1 - 40µg/L (average of 61 samples from 27 countries: 7.4µg/L). OPP has been shown to interfere with testosterone receptor binding in vitro and therefore is considered an androgen receptor antagonist. Human exposure to OPP has been documented (CDC 2005; Coelhan et al. 2006; Kruger et al. 2008).
- Nonylphenol, a non-intentionally added substance (NIAS) that can migrate from food packaging into food. It is a break-down product of trisnonylphenyl phosphite (TNPP). Nonylphenol has been shown to migrate from HDPE milk containers into milk surrogate (10% ethanol) with an average concentration of 186 ±21ng/L (at 20°C). The estrogenicity of nonylphenol is well known and has been studied in several *in vitro* and *in vivo* test systems. Humans are widely exposed to nonylphenol (Shelby et al. 1996; Loyo-Rosales et al. 2004; Calafat et al. 2005; Ogawa et al. 2006).
- Phthalates, plastic additives that have been found to migrate from PET (polyethylene terephthalate) bottles into soft drinks and yoghurt drinks. An Iranian study looked at DEHP migration dependent on time (up to 4 months) and temperature (20° and 40°C) and found levels up to 2.4mg/L. Exposure to DEHP during pregnancy has been linked to reduced masculinity in male offspring. Human exposure to DEHP is well-studied and ubiquitous (Gray et al. 2000; Farhoodi et al. 2008; Swan 2008)

Many questions remain unanswered: How large is the contribution of food packaging to the overall human exposure to these endocrine disrupters? How does this constant, long term exposure affect development of chronic disease?

Exposure to endocrine disrupters is especially of concern for women and men of childbearing age, as these compounds might affect their reproductive ability or the health of their offspring. While much remains unknown to date it is clear that precautionary approaches must include awareness for the sources of such compounds, i.e. plastic-based food packaging materials.

Environmental Aspects of Plastic Food Packaging

Apart from leaching potentially harmful compounds into food, plastic packaging also can negatively impact our natural environment, and so ultimately harm human health. When not disposed of properly, plastic packaging can get into the environment.

The North Pacific central gyre is an area of high atmospheric pressure with a clockwise ocean current, where debris and its fragments naturally accumulate. In this area winds and currents diminish, leaving floating trash to accumulate and form a kind of "plastic soup" (Moore et al. 2001). This aggregate of floating plastic litter has been termed the Great Pacific Garbage Patch (http://www.mindfully.org/Plastic/Ocean/Pacific-Garbage-Patch27oct02.htm).

> "The trash vortex is an area the size of Texas in the North Pacific in which an estimated 6 kilos of plastic for every kilo of natural plankton, along with other slow degrading garbage swirls slowly around like a clock, choked with dead fish, marine mammals, and birds who get snared." (source: http://oceans.greenpeace.org/en/our-oceans/pollution/trash-vortex)

Bits of plastic are being washed up on beaches across the world. Dr. Curtis Ebbesmeyer of the Beachcombers and Oceanographers International Association estimates that "[…] a single, 1 L plastic water bottle will photodegrade into enough small pieces to put one piece on every mile of beach in the world." (Moore 2008) The proliferation of plastic particles is an eyesore, but also poses a threat to marine wildlife when the plastic is mistaken for food.

Furthermore, plastic particles act like sponges for persistent pollutants like PCBs, dioxins, DDT etc. and accumulate in them. When these pollutant-enriched plastic bits are eaten by fish, birds and other animals, the pollutants enter the food chain. In the long-term it is plausible that they will end up increasingly on our dinner plates.

Plastics – is there an Alternative?

Managing this pollution is a nearly impossible task. Therefore, environmentalists are calling for substitution of plastic packaging and other articles with biodegradable materials (Kubota et al. 2005).

Bioplastics have entered the scene, promising "sustainable" alternatives to conventional petroleum-based plastic materials. Currently, the term "bioplastics" is used for three quite different types of materials:

1. plastics that have a petroleum-based feed stock but that are biodegradable
2. plastics that are made from a renewable source but are non-biodegradable
3. and plastics made from a renewable source and that are biodegradable (currently there is no industrial process in place that exclusively uses renewable sources)

Satisfying the plastic consumption of the entire world with bioplastics made from renewable sources would mean a direct competition with food producing agriculture for arable land. Intensive agriculture implies use of fertilizers and possibly pesticides, which again has an impact on the environment. Ideally, bioplastics would be produced from organic wastes. However, the centralized collection of such wastes poses a challenge.

Currently the market for bioplastics is small, with around 0.15% of the total plastics market. Forecasts for market shares show an increase, albeit the overall market share will remain low during the next few years (Figure 1).

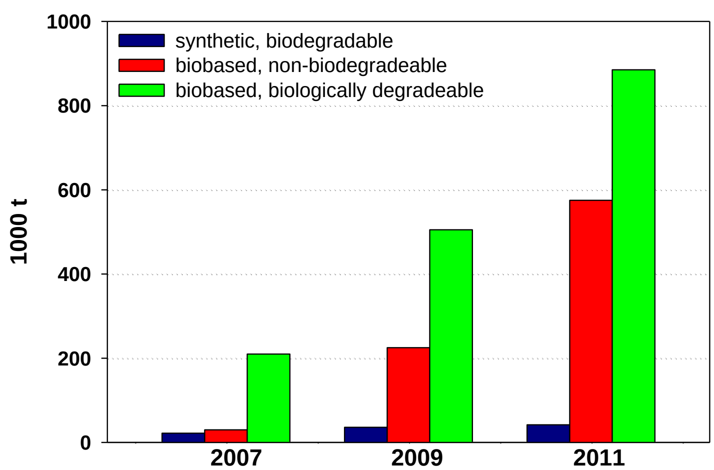

Figure 1: Global bioplastics production capacities forecast (data source: European Bioplastics, in: (Hermann 2008))

Source Control as the Sustainable Way Forward

Our current reality is that we are spreading synthetic chemicals that pose a risk to human health in a large scale, via food packaging and other routes. This practice is not in agreement with the concept of Sustainable Development. Protecting human health and our environment however will require more than just technical innovation like the use of barriers in packaging. We are faced with the need for a paradigm shift, away from solving pollution problems to preventing them in the first place.

This paradigm shift calls for source control of harmful chemicals. In the context of food packaging this means that source control must be practiced at all levels of production, use and disposal, to avoid the spreading of harmful chemicals. The 12 Principles of Green Engineering can also be instrumental for designing new packaging, where the ideal packaging will strike a balance between all 12 concepts (Anastas and Zimmerman 2003). According to Anastas and Zimmerman, two fundamental concepts designers should strive to integrate at every opportunity are *life cycle considerations* and the first principle of green engineering, *inherent non-hazardousness* (Table 1). Key to this approach is the use of safe, nontoxic alternatives where available.

Table 1: The 12 Priniples of Green Engineering. Designers of products, like food packaging, can use these concepts to achieve designs that are in line with the concept of Sustainable Development. Considerations of life cycle and inherent non-hazardousness should always be met. (reproduced from (Anastas and Zimmerman 2003)).

The 12 Principles of Green Engineering

Principle 1:	Designers need to strive to ensure that all material and energy inputs and outputs are as inherently nonhazardous as possible.
Principle 2:	It is better to prevent waste than to treat or clean up waste after it is formed.
Principle 3:	Separation and purification operations should be designed to minimize energy consumption and materials use.
Principle 4:	Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.
Principle 5:	Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.
Principle 6:	Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.
Principle 7:	Targeted durability, not immortality, should be a design goal.
Principle 8:	Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.
Principle 9:	Material diversity in multicomponent products should be minimized to promote disassembly and value retention.
Principle 10:	Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.
Principle 11:	Products, processes, and systems should be designed for performance in a commercial "afterlife".
Principle 12:	Material and energy inputs should be renewable rather than depleting.

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