Chemosphere 74 (2009) 1195–1200

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Leachates from plastic consumer products – Screening for toxicity with *Daphnia magna*

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ARTICLE INFO

Article history:
Received 12 August 2008
Received in revised form 10 November 2008
Accepted 12 November 2008
Available online 23 December 2008

Keywords:
Acute toxicity
Leaching test
Toxicity Identification Evaluation
Plasticised PVC
Polyurethane
CD-R

ABSTRACT

Plastic products can contain chemicals that are hazardous to human health and the environment. In this study, it was investigated if various plastic products emit hazardous chemical substances to water. Two leaching methods (batch and diffusion tests) were used and the leachates were tested for acute toxicity to *Daphnia magna*. Nine out of 32 tested plastic product leachates had *Daphnia* 48-h EC_{50}s ranging from 5 to 80 g plastic material L^{-1}. For the remaining 23 products no effect on mobility was seen even at the highest test concentrations (70–100 g plastic material L^{-1}). A compact disc (recordable) was the most toxic plastic product, but the toxicity was traced to the silver layer not the polycarbonate plastic material. The other products that displayed toxicity were made of either plasticised PVC (artificial leather, bath tub toy, inflatable bathing ring and table cloth) or polyurethane (artificial leather, floor coating and children's handbag). While the Toxicity Identification Evaluation (TIE) for compact discs using sodium thiosulfate addition showed that silver was causing the toxicity, the TIE for artificial leathers using C18 cartridges showed that hydrophobic compounds were causing the toxicity. Acute toxicity tests of plastic product leachates were found to be useful for screening purposes for differentiating between toxic and non-toxic products.

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1. Introduction

Release and dispersal of hazardous chemicals from consumer products (articles), e.g. plastic products, are of concern due to the continuous increase in production and global consumption of chemicals and articles. Plastics are composed of polymers that determine the plastic type and additives (e.g. antioxidants, stabilisers, plasticisers, flame retardants, and catalysts) that enable processing or give the plastic its desired properties in a certain application (OECD, 2004). The high molecular mass polymers per se are inert and are not hazardous from a toxicity point of view (Sheftel, 2000). Their large size limit transport across biological membranes and they are not particularly reactive (Anastas et al., 2000). Instead it is the presence of additives, low molecular mass polymers and unpolymerised residual monomers as well as reaction, transformation and destruction products that mainly determine the migration potency of chemical substances from polymeric materials (Sheftel, 2000). Many of these substances are either weakly bound or not bound at all to the polymeric macromolecules (OECD, 2004).

Several plastics additives and monomers are hazardous to human health and the environment. Examples of properties for some additives and monomers are: toxic for reproduction (e.g. di(2-ethylhexyl) phthalate (DEHP) and bisphenol A), carcinogenic (e.g. vinyl chloride, acrylonitrile, benzene and 1,3-butadiene), allergenic (e.g. formaldehyde, acrylonitrile, toluene diisocyanate (TDI) and methyl methacrylate), mutagenic (e.g. benzene, phenol, and 1,3-butadiene), high chronic toxicity (e.g. benzene), very high acute toxicity (e.g. phosgene and TDI) and environmentally hazardous with long term effects (e.g. pentabromodiphenyl ether (PeBDE), acrylonitrile and TDI; ECB, 2008). Brominated flame retardants and phthalates used in plastic products are widely spread in the environment today (Darnerud, 2003; Heudorf et al., 2007).

Presently only some plastic consumer products have restrictions on either contents or migration of certain hazardous chemical substances. One example is plastic materials or articles intended to come into contact with foodstuffs. In the European Union these are regulated through a positive list of allowed chemical substances, where migration concentrations are specified (European Commission, 2002) and rules for testing migration are laid down (European Council, 1982).

The potential release of hazardous chemicals from plastic products have previously been studied with migration tests for migration to a contact media (e.g. Maragou et al., 2008; Özlem, 2008; Westerhoff et al., 2008), leaching tests for leaching to water (e.g. Kim et al., 2006), extraction tests using extraction fluids to enhance leaching (e.g. Pors and Fuhlendorff, 2003; Bradley et al., 2007; Fernandes et al., 2008), and emission tests for Volatile Organic Compound (VOC) emissions (e.g. Lundgren et al., 1999;

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doi:10.1016/j.chemosphere.2008.11.022

Hansen et al., 2004). Leaching tests on plastic products with subsequent aquatic toxicity tests used in the present study have, according to our knowledge, not been made previously.

The aim of this study was to investigate if various plastic products will emit hazardous chemical substances to water in concentrations causing acute toxic effects, and also to evaluate the leaching methodology and aquatic acute toxicity testing procedure on leachates from plastic products when screening for toxicity.

2. Materials and methods

In a series of laboratory experiments screening for acute toxicity was made on 32 different newly bought plastic products, with 15 different plastic types and various applications represented (Table 1). Deionised water was chosen as leaching medium because a medium was needed in which the test organisms, after addition of stock solutions, can survive. In addition this leachate can be used for chemical analysis, without interferences.

2.1. Sample preparation and batch leaching tests

A one stage batch leaching test based on CEN (2002) was selected for several reasons. Deionised water is used as a leaching medium. Particle size reduction enables testing of products with irregular shape and may also enhance leaching by increasing the exposed surface area. The test is simple, fast and inexpensive, allowing several products to be tested simultaneously. However, most VOCs are probably not included in the leachate (Bjerre Hansen and Andersen, 2006).

New plastic products were cut with stainless steel scissors in 10 × 10 mm pieces and 20 g was placed in a 250 mL glass bottle. No pre-washing of the products was made, so the first leaching water was being tested. Two replicates were made for each product, and 200 mL of deionised water (ultra pure water, Elgastat Maxima, HPLC) was added, giving a concentration of 100 g plastic material L^{-1}, equivalent to a liquid to solid ratio (L/S) of 10 L kg^{-1}. Caps were screwed on. Three bottles with deionised water were used as controls. All bottles were

Table 1
Plastic products (32) and plastic types (15) tested in this study with leaching tests and subsequent acute toxicity tests with *Daphnia magna*.

No.	Plastic product	Plastic type	Field of application	Description
1[a]	Compact disc, recordable (CD-R)	Polycarbonate (PC)	For storing digital data	80 min 700 MB, silver, azo-metal complex
2[a]–3[a]	2 Artificial leathers (brand S, M)	Polyvinyl chloride (PVC)[b]	Upholstery for marine environment	100% PVC (front), 100% polyester (back)
4[a]	Artificial leather (brand G)	Polyurethane (PU)	Upholstery for marine environment	100% PU (front), cotton and polyester (back)
5[a]	Floor	Polyvinyl chloride (PVC)[b] and polyurethane (PU) surface	For public premises, housing and industry	PVC 47%[c], DINP and epoxidized soy bean oil 17 %[c], PU surface reinforcement
6[a]	Children's handbag	Polyurethane (PU)	For carrying small things	Disney print; 100% PU (outside), 100% nylon (inside)
7[a]	Bath tub squirt toys	Polyvinyl chloride (PVC)[b]	Toy for bath tub, for children ⩾6 months old	Soft, squeezable animals
8[a]	Inflatable bathing ring	Polyvinyl chloride (PVC)[b]	Floating aid for children ⩾10 years old	Thin (<1 mm)
9[a]	Table cloth	Polyvinyl chloride (PVC)[b]	Protecting tables	Transparent, slightly adhesive
10	Bib	Polyethylene (PE)	Garment for babies protecting clothes, dish washable	Semi-soft, flexible, printed
11	Floor (wet room)	Polyvinyl chloride (PVC)[b]	For public premises, housing and industry	PVC 38%[c], DINP 16%[c]
12	Foam mattress	Polyurethane (PU)	For chair cushion	Polyether foam of PU, 41 × 42 × 4 cm
13	Foldable water container	Polyethylene (PE) or polypropylene (PP)	For collecting and storing water (camping)	Semi-soft, flexible
14	Garbage bag	Low-density polyethylene (LDPE)	For collecting garbage	125 L, black, recycled PE
15	Iron on beads	Polyethylene (PE)	For bead boards and necklaces	Pipe shaped, 2 × 5 mm
16	Pedestrian prism reflector	Polystyrene (PS)	Enhancing visibility in darkness	Hard, transparent
17	Plastic cup	Polystyrene (PS)	Disposable cup for beverage	Ribbed, thin, flexible, 12 cl
18	Plate	Melamine	For food, multiple use	Hard
19	Plexiglas	Polymethyl metacrylate (PMMA)	Substitute material for glass	Transparent acrylic sheet
20	Polar fleece textile fabric	Polyethylene terephthalate (PET)	For clothes and blankets	Multicoloured
21	Rain pant	Polyester	Protection against rain for kids	100% polyester (front)
22	Shovel for sandpit	High-density polyethylene (HDPE)	For play in sandpit	Hard, 25 cm in length
23	Tefex baking sheet	Polytetrafluoroethylene (PTFE)	Covering baking oven plates, reusable, non stick	Woven fabric coated with Teflon (PTFE) (Tefex®)
24	Hand protection glove	Polyvinyl chloride (PVC)[b]	Hand protection against chemicals	PVC (outside), woven fabric (inside)
25–29	5 Drinking water pipes	4 polyethylene (high-density (HDPE) and medium-density (MDPE)); 1 acrylonitrile butadiene styrene (ABS)	Transport of drinking water under ground, by pressure	Diameter: 90–110 mm (outside), 73–101 mm (inside)
30–32	3 Ground pipes	2 polypropylene (PP); 1 polyvinyl chloride (PVC)	Transport of surface and waste water under ground, by gravity	Diameter: 110 mm (outside), 101–104 mm (inside)

[a] Plastic products displaying toxicity see Fig. 1.
[b] Plasticized (soft).
[c] By weight.

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