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Degradation of specific aromatic compounds migrating from PEX pipes into drinking water

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ABSTRACT

Nine specific compounds identified to migrate from polyethylene (PE) and cross-linked polyethylene (PEX) to drinking water were investigated for their degradation in drinking water. Three sample types were studied: field samples (collected at consumer taps), PEX pipe water extractions, and water samples spiked with target compounds. Four compounds were quantified in field samples at concentrations of 0.15–8.0 μg/L. During PEX pipe water extraction 0.42 ± 0.20 mg NVOC/L was released and five compounds quantified (0.5–6.1 μg/L). The degradation of these compounds was evaluated in PEX-pipe water extractions and spiked samples. 4-ethylphenol was degraded within 22 days. Eight compounds were, however, only partially degradable under abiotic and biotic conditions within the timeframe of the experiments (2–4 weeks). Neither inhibition nor co-metabolism was observed in the presence of acetate or PEX pipe derived NVOC. Furthermore, the degradation in drinking water from four different locations with three different water works was similar. In conclusion, eight out of the nine compounds studied would – if being released from the pipes - reach consumers with only minor concentration decrease during water distribution.

1. Introduction

Since the 1980's, the polymers PE (polyethylene) and PEX (cross-linked polyethylene) have increasingly replaced materials such as cast iron, concrete and copper in drinking water distribution systems. In Denmark, virtually all new drinking water pipes are made of PE, and they comprised approximately 16% of the pipeline system in 2002 (Vandpanelet, 2004). The renewal of old pipelines with PE pipes is 0.8–1.5 % per year. PEX is preferred for household installations because of its flexibility and heat resistance, making it usable for both hot and cold water installations. PE is preferred for larger pipes in distribution systems because of robustness and strength.

Studies of PE and PEX influence on water quality have mainly focused on after-growth potentials (e.g. Tsvetanova and Hoekstra, 2009; Corfitzen et al., 2002; Van der Kooij et al., 2006) or alteration of odor and taste (e.g. Anselme et al., 1985; Villberg et al., 1998; Durand and Dietrich, 2007). Few investigations have focused on the release of specific compounds to drinking water (Brocca et al., 2002; Nielsen et al., 2007; Skjevrak et al., 2003, 2005; Kowalska et al., 2011; Lund et al., 2011).

Increased use of PE and PEX pipes for both new installations and maintenance of existing networks (Vandpanelet, 2004), may increase concentrations of migrating compounds at consumers tap. Elevated biofilm production in PEX pipes compared with copper and stainless steel (Van der Kooij et al., 2005), demonstrates that PEX releases bio-assimilable carbon, i.e. carbon that can be used by microorganisms as source of energy and carbon. However, little is known about the degradability of specific compounds migrating from PEX, how they contribute to the fraction of assimilable carbon or whether the composition of assimilable carbon can affect the degradation of specific compounds. Concentrations of specific compounds in drinking water from household installations are low, i.e. below 2.9 μg/L in field investigations and below 5.9 μg/L in laboratory investigations with six new PEX pipes, reported by Nielsen et al. (2007). This investigation included eight of the nine investigated compounds in this study, Table 1 (XIV was not

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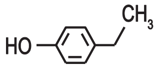
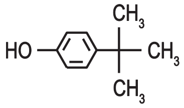
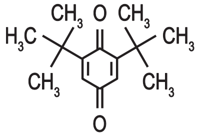
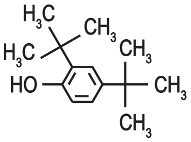
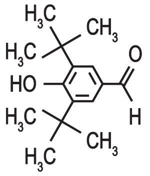
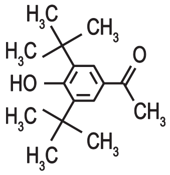
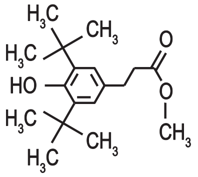
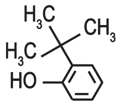
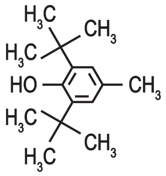
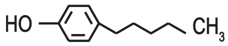
Table 1
Analytes quantified in the experiments with name, limit of detection (LOD), limit of quantification (LOQ) and structure presented. Chemical properties, purities and suppliers can be found in the supplementary data.

Analyte ID	Chemical name (CAS no.)	LOD LOQ [μg/L]	Structure
I	4-ethylphenol (123-07-9)	0.23 0.60	
II	4-tert-butylphenol (98-54-4)	0.15 0.33	
III	2,6-di-tert-butyl-p-benzoquinone (719-22-2)	0.50 0.59	
IV	2,4-di-tert-butylphenol (96-76-4)	0.18 0.39	
VI	3,5-di-tert-butyl-4-hydroxybenzaldehyde (1620-98-0)	0.22 0.57	
VII	3,5-di-tert-butyl-4-hydroxyacetophenone (14035-33-7)	0.20 0.52	
IX	3-(3,5-di-tert-butyl-4-hydroxyphenyl) methylpropanoate (6386-38-5)	0.16 0.40	
XIV	2-tert-butylphenol (88-18-6)	0.17 0.45	
BHT	2,6-di-tert-butyl-4-methylphenol (128-37-0)	0.29 0.57	
Internal standards			
npp	n-pentylphenol (14938-35-3)		
DBHT (deuterated BHT)	2,6-Di(tert-butyl-d$_9$)-4-methyl (phenol-3,5,O-d$_3$) (64502-99-4)