

## Organic compounds migrating from plastic pipes into water

Beata Kowalska, Dariusz Kowalski and Agnieszka Rożej

### ABSTRACT

Case studies were carried out to identify potential chemical contaminants migrating to drinking water from polyvinyl chloride (PVC) or polyethylene (PE) pipes, available on the Polish market. Analyses were carried out by gas chromatography (GC) coupled with mass spectrometry (MS). Analysis of organotin compounds in water in contact with PVC pipes from different manufacturers found variability: monobutyltin (169 and 425 ng/L) and dibutyltin (51–72 and 249–263 ng/L) were detected in two of three samples, A1 and A2 respectively. Tributyltin was detected only in the second of these (92 ng/L). No organotin compounds were detected in sample A3, but a considerable quantity of lead (0.13–0.82 mg/L) was observed. Nineteen organic compounds, also volatile organic compounds such as xylene, styrene, phenols, and ethylmethylbenzene, were identified during GC-MS analysis of water samples in contact with high density PE pipe. Phenolic compounds related to antioxidants such as di-*tert*-butyl-hydroxytoluene (0.29–3.6 and 0.84–9.8 ppb) and their degradation products such as *t*-butyl-methylphenol (0.9–11.8 ppb) were also detected.

**Key words** | planning and scheduling, pollution, water supply

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### INTRODUCTION

In recent years, there has been a great increase in the use of plastic pipes in drinking water distribution systems and household installations. Polyethylene (PE) and polyvinyl chloride (PVC) pipes are greatly preferred for several reasons, such as ease of installation, ease of cutting, excellent stiffness, decreased water noise, resistance to corrosion, and an ability to tolerate slight displacement and soil movement without damage to their mechanical properties. However, some organic compounds may leach from polymeric materials and cause contamination of water. Organic polymeric materials are potentially capable of leaching monomers, low molecular weight polymer units and additives such as antioxidants, lubricants, softeners, colouring agents and applied solvents (Tomboulou *et al.* 2004). This has been shown by some authors who found organic compounds, herein volatile organic compounds (VOCs), leaching from PE and cross-linked PE (PEX) material (Koch 2004; Skjevrak *et al.* 2003). Organotin compounds and lead have been found in drinking water distributed

through PVC pipes (Sadiki *et al.* 1996; Sadiki & Williams 1998; Al-Malack 2001).

About 100 different organic compounds have been found to migrate to water from PE and PEX pipes (Koch 2004; Skjevrak *et al.* 2003). Anselme *et al.* (1985), Brocca *et al.* (2002) and Skjevrak *et al.* (2003) showed that phenols and quinones were found in water exposed to high density polyethylene (HDPE) pipes or PE pipes. Compounds such as esters, aldehydes, ketones, terpenoids and aromatics are known to migrate as well, and may be used as nutrient sources for microorganisms in biofilms (Skjevrak *et al.* 2003). Brocca *et al.* (2002) found that the maximum concentration of 2,6-di-*tert*-butyl-p-benzoquinone released from HDPE pipes was 1.5 µg/L, and five other phenols were found in concentrations greater than 0.05 µg/L. Hem (2002) identified VOCs such as xylene, styrene, phenols and ethyl benzene. Skjevrak *et al.* (2003) quantified VOCs in seven experimental setups, their concentrations ranged between 1.3 µg/L and 8.4 µg/L.

Organic compounds migrating from PE pipes can be grouped as follows (Denberg *et al.* 2007): (1) additives like antioxidants; (2) degradation products formed by radical reaction of the antioxidants; (3) broken PE chains that in general have a functional polar oxygen group (e.g. esters and aldehydes).

Stabilisers such as metal mixtures of lead, organotin, calcium, barium and cadmium are used to control degradation of U-PVC pipes during manufacturing processes. Some investigators have reported the migration of lead from U-PVC pipes into potable water (Al-Malack 2001). Several studies have investigated the leaching into drinking water of organotins used as antioxidants in PVC pipes. The presence of organotin compounds such as methyltin, dimethyltin and butyltins in water samples from PVC pipes used in Canada was first reported in 1993 by Sadiki & Williams (1993) and a follow-up pilot study confirmed the presence of organotin compounds in drinking water distributed through PVC pipes in Canada (Sadiki *et al.* 1996).

Several studies show that plastic materials enable the growth of biofilms (Niquette *et al.* 2000; Zacheus *et al.* 2000). Most of the microbial biomass in drinking water distribution systems is located within biofilms, formed on the inner surfaces of the pipes (Laurent *et al.* 1993; Zacheus *et al.* 2001).

There is not enough information about the hazards to human health from chemicals leaching from plastic pipes into drinking water. The majority of reports come from studies on animals such as rats and mice. However, it is known that microbial growth in drinking water and biofilms causes aesthetic and health problems (Percival & Walker 1999; Schewzyk *et al.* 2000). Microbiological growth in the drinking water distribution system may influence the deterioration of water quality, due to increased turbidity, heterotrophic bacteria and even pathogens (Lehtola *et al.* 2004). Leaching of VOCs may cause unwanted tastes and odours in water, lead causes neurotoxic effects and can increase blood pressure and interfere with hearing, and the neurotoxicity of trimethyltin has been extensively studied; mono- and dimethyltin are, however, considered to be relatively non-toxic (Moser *et al.* 2006). Therefore, it is important to identify compounds that migrate from plastic pipes into drinking water and to better assess the human health effects of these compounds and their degradates.

In the present case study, identification of the organic compounds migrating from PE and PVC pipes into water

was undertaken. Their presence was investigated under laboratory conditions. Three different PVC pipes and one PE pipe available on the Polish market were tested. The research was performed by means of gas chromatography-mass spectrometry (GC-MS) analysis.

The changes in water quality and biofilm formation in dynamic conditions are being studied at present in a pilot-scale water distribution system. Furthermore, research under field conditions, i.e., in water samples from pipes in a distribution system, will be reported.

## MATERIALS AND METHODS

### Plastic pipes used for testing

Four different plastic pipes, three made of unplasticised PVC, labelled A1, A2 and A3, and one made of HDPE, labelled B1, were used as samples during the laboratory study. Samples A1, A2 and A3 came from different manufacturers and differed in colour (two were white and one was grey). Test pipes were bought directly from the manufacturers. They were stored in dark place for few days. The investigation of pipes started just after their transport to the laboratory.

A migration test was conducted according to EN 12837-1. Pipe pieces had lengths of about 0.5 m and the following internal diameters: A1 and A2 – 28 mm, A3 – 21 mm and B1 – 21 mm. The pipe surface area to water volume (surface-to-volume ratio) ranged from 10 to 14 L<sup>-1</sup>. During the migration test, the inner surface of a sample was brought into contact with test water.

All solvents and reagents used were of analytical-reagent grade, and deionised water prepared with a Milli-Q apparatus (Millipore, Molsheim, Germany) was used for the preparation of all aqueous solutions.

Standard solutions for total carbon/total organic carbon (TC/TOC) analysis were prepared from potassium hydrocarbonate-puriss (POCh, Poland) and potassium hydrophthalate-puriss (POCh, Poland). Standard solutions of organotin compounds (mono-, di- and tributyltin chlorides) were obtained from Accustandards (New Haven, USA). Propylated tin standard solutions were used as an internal standard.

The ethylation solution was prepared as a 5% solution of reagent grade sodium ethylate (Merck, Germany) in ethanol (POCH, Poland).

### Migration tests

A diffusion leaching test using different plastic pipes was performed according to the EN 12837-1 standard method. This method describes a migration test based on static contact between water and a plastic pipe for three successive periods each of 72 h duration. Prior to the migration test, the pipe samples were flushed with tap water for 60 min. Immediately after this pre-treatment, the pipe lengths were filled with fresh tap water to their entire volume to eliminate headspace and capped with glass stoppers at both ends. The pipes were stored undisturbed at room temperature  $20 \pm 2^\circ\text{C}$  for 3 days, after which leachates were removed for analysis and the pipes were filled again with tap water. The filling and draining was repeated three times for each pipe. Thus, the whole leaching process persisted for nine days. At the end of each test period, the test water was removed and water samples were analysed by GC-MS. Additionally, reference tap water was also prepared for analysis.

### Water quality analysis

Analysis of the TOC concentration content of water samples was performed using an automatic SHIMADZU TOC-5050A analyser, and the parameters (e.g. furnace temperature, concentrations of phosphorous acid  $\text{H}_3\text{PO}_4$ , range and number of TC and TOC standards) described in Standard Method EN 1484-5. Determination of total carbon was based on sample oxidation carried out with  $\text{O}_2$  at  $650\text{--}700^\circ\text{C}$  and catalysed by Pt. Inorganic carbon (IC) determination was based on the measure of  $\text{CO}_2$  released from a sample after addition of  $\text{H}_3\text{PO}_4$ .

The detection limit for TC/TOC analysis was estimated at 0.1 ppm C; a quantification limit for these determinations was estimated at 0.5 ppm C. The precision of these analyses, estimated as a relative standard deviation (RSD), was better than 4% for three repetitions.

pH was measured with a CPC-551 pH meter (Elmetron) with temperature correction.

### Gas chromatography-mass spectrometry analyses

Aliquots of 25 mL of water sample or aqueous standard solution were transferred into 40 mL vials with silicon/PTFE septum (Supelco, Bellefonte, USA) and spiked with the appropriate amounts of individual or mixed standards. A volume of 2 mL of the ethylation reagent was also added, and the mixture was stirred for 45 min. A solid phase micro-extraction (SPME) device with fibre coated with 100  $\mu\text{m}$  of poly(dimethylsiloxane) (Supelco, Bellefonte, USA) was used for the extraction of analytes. To examine the effect of the extraction temperature, the vial was thermostated. After extraction of the analytes by exposing the SPME fibre to the headspace of the solution (30 min), the fibre was immediately transferred to the GC injection port for desorption of the analytes. All steps were followed precisely, as the overall reproducibility of the SPME procedure is critically dependent on equilibration conditions and time. Calibration of TOC was done by standard addition of methanolic solution of butylated tin compounds and analysis of a sample with the addition of standards – the internal standard method (Cosnier 2000; Bancon-Montigny et al. 2002).

In this procedure, monobutyltin, dibutyltin and tributyltin chlorides were transformed into their ethylated analogues.

The accuracy and precision of the method were evaluated by measuring three repeated water samples spiked to 150 ng/L monobutyltin, dibutyltin and tributyltin. The results of these determinations are given in Table 1.

Analyses were carried out using a Thermo Trace GC Ultra gas chromatograph coupled with a Polaris Q mass spectrometer under the same chromatographic conditions. The operating conditions of the GC-MS device were as follows: the carrier gas was He at a constant flow velocity of

**Table 1** | Measured concentration, retention time ( $T_R$ ), detection limits (DL), quantification limit (QL) and standard deviation (SD) and relative standard deviation (RSD) for mono-, di- and tributyltin (MBT, DBT and TBT) determination

Compound	Measured concentration (ng/L)	$T_R$ (min)	DL (ng/L)	QL (ng/L)	SD (ng/L)	RSD (%)
MBT	147.2	11.33	11	33	$\pm 3.14$	2.14
DBT	154.7	13.62	9	27	$\pm 2.75$	1.72
TBT	157.1	15.62	7	21	$\pm 2.93$	1.86

40 cm/s, and the sample was injected by a SPME device in the splitless mode into the injection port at 270 °C. Employing a capillary column (RT×5 (Restek) 60 m × 0.25 mm i.d., 0.25 µm film thickness) the oven temperature was held at 75 °C for 2 min, raised by 5 °C min<sup>-1</sup> to 300 °C, and then held at 300 °C for 5 min. The identification of the organic compounds extracted from the leached water was performed by an ion-trap system operating in 70 eV EI ionisation. The MS scan range was from 50 m/z to 370 m/z (full scan). The transfer line and ionisation source temperatures were 275 °C and 250 °C respectively.

Part of the identification of the extracted compounds leaching from the HDPE pipe was made using the reference spectra held in the NIST-2005 and Wiley 8th edition mass spectral library. To identify organotin compounds, the internal standard method was used.

### ICP-OES analysis

Inductively coupled plasma-optical emission spectroscopy (ICP-OES) JY238 Ultrace (Jobin Yvon-Horriba, France) was used to determine chemical elements leached from plastic material to water samples. Calibration standards

were prepared using multi-element Certi<sup>®</sup> VIII (Merck) solutions. The line with the highest sensitivity was used for all elements.

The sample was nebulised then transferred to argon plasma. It was decomposed, atomised and ionised, whereby the atoms and ions were excited. The intensity of the light emitted when the atoms or ions returned to lower levels of energy was measured (Zachariadis & Rosenberg 2009).

## RESULTS AND DISCUSSION

The drinking water elementary quality characteristics and TOC concentrations are presented in Table 2.

Results obtained for two (leachates from PVC pipes labelled as A1 and A2) of four water samples were found to be positive for organotin compounds. During organotin compounds analysis, the internal standard method was used (Cosnier 2000). The compounds were identified using gas chromatography by comparing retention times with internal standards. The main tin-containing decomposition products released from water samples (A1 and A2) were considered to be chloride derivatives of the original

**Table 2** | Water quality characteristics: total carbon (TC), inorganic carbon (IC) and total organic carbon (TOC)

	Pipe type	T (°C)	pH	Alkalinity (mval/L)	Hardness (mg/L)	TC (ppm)	IC (ppm)	TOC (mg/L)
Ref. <sup>a</sup>	Tap water	9.5	7.11	6.45	250.0	24.71	23.12	1.59
Test No.1								
A1	PVC white	12.5	7.35	6.50	345.0	84.09	81.28	2.81
A2	PVC white	13.0	7.36	6.60	342.5	86.54	82.14	4.40
A3	PVC grey	13.1	7.31	7.00	381.5	89.60	84.64	4.96
B1	HDPE blue	12.5	7.39	6.75	350.0	87.61	81.94	5.77
Test No. 2								
A1	PVC white	12.0	7.29	6.50	306.5	83.96	80.94	3.02
A2	PVC white	13.0	7.28	6.60	332.5	86.10	82.00	4.10
A3	PVC grey	12.0	7.29	6.50	256.5	88.02	83.21	4.81
B1	HDPE blue	14.1	7.29	6.50	237.5	88.41	82.40	6.01
Test No. 3								
A1	PVC white	11.4	7.27	6.50	312.5	84.30	81.11	3.19
A2	PVC white	12.6	7.31	6.60	367.5	87.91	83.65	4.26
A3	PVC grey	13.4	7.63	6.75	306.5	86.74	82.10	4.64
B1	HDPE blue	14.0	7.32	6.75	312.5	87.17	81.19	5.98

<sup>a</sup> Ref. – reference water.

mono-, di- and tributyltin stabilisers. The results are summarised in Table 3.

The amounts of organotin compounds in leachates from various PVC pipes differed significantly. The concentration of tetraethyltin ( $\text{SnEt}_4$ ) was 1.6 times greater in sample A2 than in sample A1. Butyltriethyltin ( $\text{SnEt}_3\text{Bu}$ ) and dibutylodiethyltin ( $\text{SnEt}_2\text{Bu}_2$ ) concentrations were 2.2 and

3.5 times greater in sample A2 than in A1 respectively. No organotin species were detected in the reference sample (tap water) or in sample A3 – grey PVC pipe. A chromatogram obtained by SPME-GC for the water sample A1 during test contact No. 2 is shown in Figure 1.

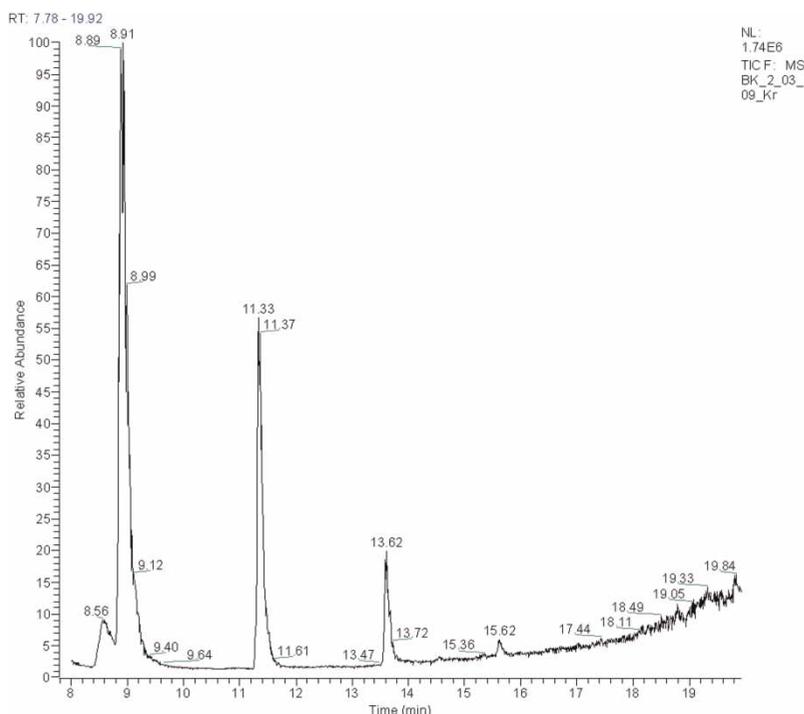
Mass spectrometry was used to provide positive identification of organotin compounds. Electron impact mass spectra (Figures 2 and 3) of the two strongest peaks (8.90 and 11.34 minutes) showed ion relative intensities for molecular clusters of  $\text{SnEt}_4$  and  $\text{SnEt}_3\text{Bu}$ . Scanning an abbreviated mass range allowed all ions of interest to be detected.

Analysis of the results indicated that monobutyltin levels in leachates from PVC pipes ranged up to 169 ng/L in sample A1 and to 425 ng/L in sample A2. Tributyltin was detected only in sample A2 and the highest level of that compound (92 ng/L) was detected in a third contact test. The concentration of dibutyltin ranged from 51 to 72 ng/L for sample A1 and from 249 to 263 ng/L for sample A2. It was found that the highest amounts of all organotin compounds, except dibutyltin and tributyltin, were washed out from samples A1 and A2 of PVC pipes

**Table 3** | Concentration of organotin compounds in leachates from PVC pipes (ng/L)

	$\text{SnEt}_4$	$\text{SnEt}_3\text{Bu}$	$\text{SnEt}_2\text{Bu}_2$	$\text{SnEtBu}_3^a$
<b>A1</b>				
Test No. 1	295	169	72	ND <sup>b</sup>
Test No. 2	273	152	51	ND
Test No. 3	275	146	62	ND
<b>A2</b>				
Test No. 1	488	379	254	88
Test No. 2	432	368	263	71
Test No. 3	378	425	249	92

<sup>a</sup> Tributyltin, <sup>b</sup> not detected.



**Figure 1** | Chromatogram for water sample (A1 – white PVC pipe) for analysis of organotin compounds (extracted ions).

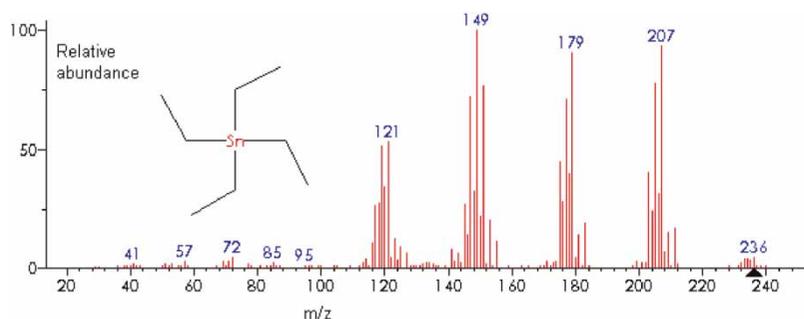


Figure 2 | Ion relative intensities for molecular cluster of SnEt<sub>4</sub>.

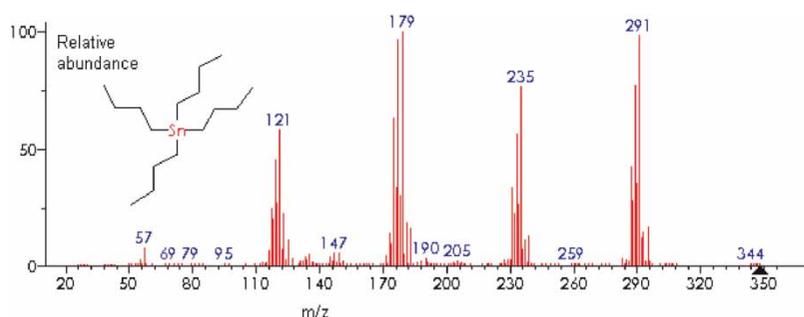


Figure 3 | Ion relative intensities for molecular cluster of SnEt<sub>3</sub>Bu.

during the first contact test. The concentrations of dibutyltin and tributyltin varied in A2 leachates without a clear trend. The highest levels of organotin compounds, especially mono- and dibutyltin, were detected in sample A2.

No organotin compounds were detected in sample A3. In order to assess the concentrations of different elements (especially heavy metals) in water samples, ICP-OES analysis was performed. The results are summarised in Table 4. The highest levels of lead (shown in bold) were leached from the PVC pipes labelled A3. It is possible that these pipes were stabilised by means of lead-based systems. The concentrations of lead in the A3 samples ranged from 0.13 mg/L to 0.82 mg/L and were highest during the first contact period of the leaching test. The lead concentration in sample A3 in test No. 1 was eight times higher than the maximum concentration level in drinking water, set within EU Directive 98/83/WC (European Parliament and Council of the European Union 1998).

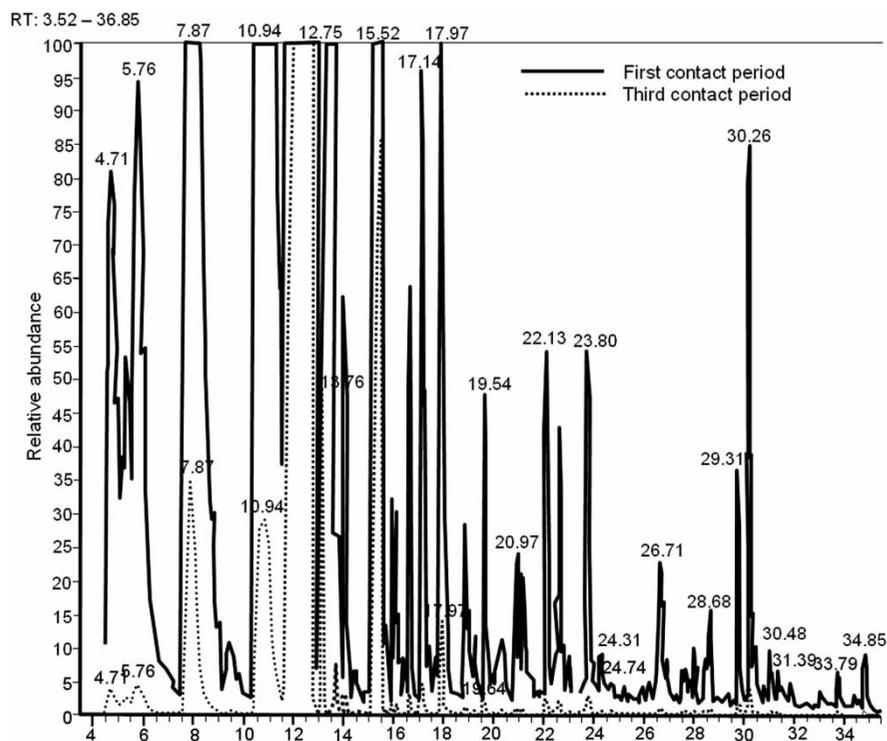
Water exposed to either the HDPE or PVC pipes for 72 h in static conditions showed elevated TOC values. The highest values of TOC, about 6 mg/L, were observed in

HDPE leachates (B1). The TOC concentrations in PVC leachates (A1, A2 and A3) were lower and constituted respectively 50%, 76% and 86% of values for HDPE in the first contact test. The amounts of TOC leached from both HDPE and PVC pipes did not change with subsequent flushes. The organic compounds identified in the leachates from HDPE pipes were analysed by GC-MS.

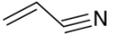
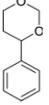
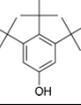
A variable number of peaks of different intensities are shown in Figure 4 where the two chromatograms (tests No. 1 and No. 3) have been superimposed. The results concerning some of these peaks are shown in Table 5. During the mass spectra interpretation, the structural identification of chemicals was initially accomplished by comparison with spectra in the MS library. The origins of these compounds are probably either degradation products produced from original additives during extrusion in the pipe manufacturing process, or by-products or impurities resulting from the synthesis of pure additives. In order to investigate these hypotheses, further investigations are required. The source of *t*-butyl-methylphenol found in leachates from HDPE

**Table 4** Concentrations of metal cations in leachates from PVC and HDPE pipes (mg/L)

Sample	K	Mg	Ca	Cd	Co	Cr	Cu	Fe	Al	Mn	Ni	Pb	Sr	Zn
Ref. <sup>a</sup>	4.47	25.7	154	ND	ND	ND	ND	0.04	0.28	0.01	ND	0.05	2.50	1.19
A1	PVC													
No. 1	3.94	25.9	147	ND	ND	ND	ND	0.01	0.33	0.02	ND	0.02	2.40	3.40
No. 2	3.80	25.6	149	ND	ND	ND	ND	0.01	0.39	0.01	ND	0.01	2.00	1.38
No. 3	3.60	24.9	151	ND	ND	ND	ND	0.05	0.31	0.02	ND	0.02	1.69	1.25
A2	PVC													
No. 1	4.00	25.7	154	ND	ND	ND	ND	0.01	0.40	0.01	ND	0.01	2.20	3.12
No. 2	3.90	25.3	149	ND	ND	ND	ND	0.01	0.31	0.01	ND	0.01	1.97	2.75
No. 3	3.70	25.7	162	ND	ND	ND	ND	0.04	0.22	0.01	ND	0.01	1.70	1.69
A3	PVC													
No. 1	4.00	25.3	152	ND	ND	ND	ND	0.04	0.34	0.01	ND	<b>0.82</b>	2.10	1.12
No. 2	3.60	25.8	144	ND	ND	ND	ND	0.06	0.34	0.01	ND	<b>0.61</b>	2.01	1.53
No. 3	3.50	24.7	162	ND	ND	ND	ND	0.01	0.26	0.01	ND	<b>0.13</b>	1.89	1.87
B1	HDPE													
No. 1	3.97	24.7	139	ND	ND	ND	ND	0.01	0.36	0.01	ND	0.01	2.09	1.34
No. 2	3.70	25.8	156	ND	ND	ND	ND	0.02	0.33	0.01	ND	0.01	1.89	1.23
No. 3	3.60	24.6	160	ND	ND	ND	ND	0.06	0.24	0.01	ND	0.01	1.68	1.38

<sup>a</sup> Ref. – reference water.**Figure 4** Chromatogram for water sample (B1 – blue HDPE pipe) for analysis of organic compounds (extracted ions) (comparison of the leachates No. 1 – solid line and No. 3 – dotted line).

**Table 5** | Compounds identified in water samples in contact with HDPE material

RT (min)	Structure	Compound	Concentration in successive tests (µg/L)			Tap water	CAS <sup>a</sup> monitored ions
			No. 1	No. 2	No. 3		
4.71		Propenenitrile	4.2 ± 0.52	3.8 ± 0.29	3.4 ± 0.29	ND <sup>b</sup>	107-13-1 (53; 52)
5.76		Benzene	17.44 ± 1.2	6.82 ± 0.56	6.85 ± 0.57	4.15 ± 0.33	71-43-2 (78; 77)
7.83		Toluene	17.44 ± 0.95	9.60 ± 0.68	8.24 ± 0.72	6.72 ± 0.56	108-88-3 (91; 92)
10.71		Xylenes	23.12 ± 1.23	19.2 ± 1.12	15.1 ± 1.10	12.1 ± 1.4	O 95-47-6 M 108-38-3 P 106-42-3 (91; 106)
11.66		Styrene	74 ± 2.43	21.6 ± 2.15	12.3 ± 0.89	ND	100-42-5 (104; 102)
13.21		Ethylmethylbenzene	13.10 ± 0.76	0.95 ± 0.09	ND	ND	611-14-3 (105; 120)
13.76		Phenol	7.3 ± 0.86	3.8 ± 0.29	0.9 ± 0.12	ND	108-95-2 (94; 66)
13.78		Mesitylene	15.3 ± 0.87	1.8 ± 0.06	0.9 ± 0.08	ND	108-67-8 (105; 120)
14.50		Methylstyrene	29.4 ± 0.99	6.2 ± 0.58	ND	ND	98-83-9 (118; 117)
15.65		Phenyl-m-dioxane	4.14 ± 0.52	ND	ND	ND	772-00-9
17.17		t-butyl-methylphenol	11.8 ± 0.65	0.9 ± 0.05	ND	ND	2409-55-4 (149; 121; 164)
18.02		Indane	0.75 ± 0.09	ND	ND	ND	496-11-7 (117; 118)
19.66		Methylindene	0.29 ± 0.08	ND	ND	ND	767-59-9 (130; 129; 115)
22.13		BHT, ditertbutylhydroxytoluene	9.8 ± 0.84	3.6 ± 0.29	ND	ND	128-37-0 (205; 220)
22.75		3-phenyl-1-pentene	3.6 ± 0.54	ND	ND	ND	19949-22-9 (117; 146)
23.81		Naphthalene	0.21 ± 0.09	0.17 ± 0.09	0.19 ± 0.09	0.18 ± 0.09	91-20-3 (128)
23.90		Dihydronaphthalene	0.19 ± 0.09	ND	ND	ND	447-53-0 (130)
26.70		2-phenyl-pentenal	6.32 ± 0.61	0.9 ± 0.09	ND	ND	24401-36-3 (91; 131)
30.26		Tertiarybutylphenol	12.24 ± 0.89	2.80 ± 0.72	2.60 ± 0.57	ND	732-26-3 (247; 262)

<sup>a</sup> Reference provided by Chemical Abstract Service (CAS), <sup>b</sup> not detected.

was residues from ditertbutyl-hydroxytoluene derivative. Some of the leached compounds are VOCs.

During the third contact period, a decrease in the leaching of organic compounds is evident (Figure 4). From reports in literature (Skjevrak et al. 2005) it is known that, in operational full-scale networks, results may be quite different. Therefore further investigation should be carried out over longer periods.

Peaks from the GC-SPME analysis were identified with the help of a mass spectrometry detector Polaris Q by comparison with spectra in the MS library.

## CONCLUSIONS

Case analyses identifying potential chemical contaminants migrating from PVC and PE pipes to drinking water were carried out. It can be concluded that all pipes showed different patterns of compound release.

The results for organotin compounds in PVC pipes showed that not all compounds were detected in all brands of pipe. This shows the variability associated with polymer synthesised by different manufacturing processes. Monobutyltin and dibutyltin were detected in two of three water samples which were in contact with PVC pipes. Tributyltin was detected only in one case.

No organotin compounds were detected in sample A3, but in this sample a considerable quantity of lead was observed. Lead was found in concentrations above the recommended Polish drinking water standard of 0.025 mg/L. Poland currently has no recommended values for organotin compounds in drinking water.

Nineteen organic compounds were identified during GC-MS analysis of water samples, which were in contact with the HDPE pipe. Some of the leached compounds are VOCs such as xylene, styrene, phenols and ethylmethylbenzene. Some of the compounds were likely to be impurities or degradation products of additives employed in the pipe extrusion. Some VOC compounds can give taste and odour to drinking water, benzene shows high chronic toxicity and phenol is mutagenic (Lithner et al. 2009).

Unfortunately, organoleptic properties and/or the health effects data for many of the compounds used in complex material formulations are not known or are not generally available.

Due to the limited number of studies about chemicals leaching from plastic pipes into drinking water and about their hazards to human health, it is important to identify potentially harmful compounds.

A larger scale study should be carried out over longer time periods, and as a field study in the water distribution system, to determine whether or not leaching of organic compounds is a continuing process. Testing should be carried out in order to better assess the human health effects of these compounds and their degradates.

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