Chemical migration from reusable plastic drinking bottles for children

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Introduction

Several studies indicate that hundreds of chemicals are present in plastic food contact materials (FCM). Many of them are harmful to our health and/or the environment.

We wanted to establish which chemicals migrate from plastic drinking bottles for children into the liquid content. Children use drinking bottles on a daily basis and it is therefore important that the materials from which the bottles are made do not expose them to harmful chemicals. Children are more vulnerable to chemical exposure due to their rapid metabolic rate, high surface area to body weight ratio, and fast-growing organs and tissues.

This paper summarizes and presents the results of a study conducted by Tegengif/Erase all Toxins (Netherlands) and McGill University (Canada). Partners are Forbrugerrådet Tænk Kemi (Denmark), Arnika (Czech Republic), Zero Waste Latvija (Latvia), Zero Waste Europe, and Rezero (Spain). To the best of our knowledge, this is the first multi-country study into the migration of chemicals from plastic drinking bottles.

Children are more vulnerable to chemical exposure.

Methodology and results

This is the first multi-country study into the migration of chemicals from plastic drinking bottles.

A total of 195 plastic drinking bottles (39 sample types, five replicates per sample type) were obtained in 2023 from stores in the Netherlands, Denmark, the Czech Republic, Latvia, and Spain. Samples were shipped to Montreal for analysis at McGill University. One replicate of each sample type was kept in the Netherlands to establish the type of plastic.

ESTABLISHING PLASTIC TYPE VIA INFRARED ANALYSIS

The polymer type for each bottle was confirmed using Fourier Transform Infrared Spectroscopy (FTIR) analysis. The distribution is presented in the figure below.

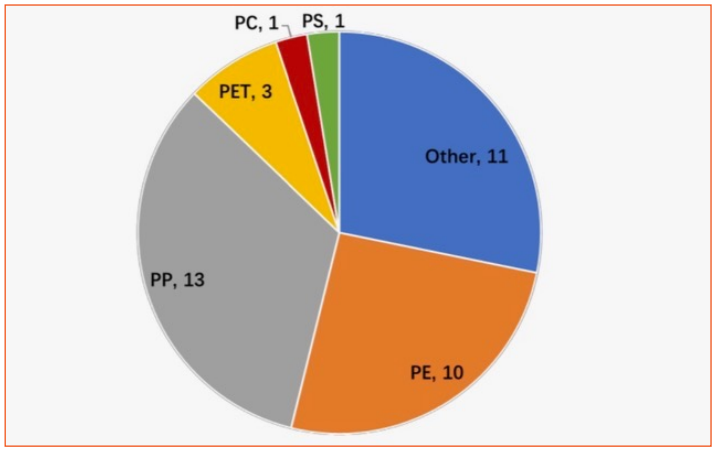


Figure 1.
Distribution of materials among the bottle samples based on FTIR analysis
PE: Polyethylene. PP: Polypropylene. PET: Polyethylene terephthalate.
PS: Polystyrene. PC: Polycarbonate. Other category: unspecified polyester.

DISHWASHING

Two replicates of every bottle sample type were washed for 20 consecutive cycles in a countertop dishwasher under standard conditions (not-eco program) with temperatures around 65°-70°C. Two other replicates remained unwashed. Four amber glass jars were used as control blank samples: two replicates were washed and two remained unwashed.

FILLING THE BOTTLES

The bottles were filled with food simulant B (acetic acid 3%) to mimic hydrophilic food with pH<4.5. The leaching of chemicals into the food simulant was analyzed for the two washed replicates and their unwashed equivalents after 24 hours and after 10 days.

TARGET ANALYSIS

The laboratory carried out a target analysis of 36 chemicals commonly found in plastics. Of the 36 targets, **Diisobutyl phthalate (DIBP)** was detected in the food simulant. Twenty-two of the 39 bottle types were shown to leach DIBP. The levels of DIBP in individual bottles/replicates are presented in Table 1. After 20 cycles of dishwashing, DIBP was found to migrate from bottles made of both **Polypropylene (PP) (13 bottle types) and Polyethylene (PE) (9 bottle types)**. Only **one unwashed** bottle type made of **PE** leached DIBP. In all 22 bottle types, the measured migration levels in the food simulant were higher after 10 days compared to 24 hours.

Table 1: Levels (ng/mL) of DIBP detected in food simulants in contact with the bottles.

SAMPLE ID	LC-MS DATE FILE	DAY 1 (NG/ML)	DAY 10 (NG/ML)	MATERIAL (IR)	COLOR
LV 02-1	23092TL-Bottle 005.d	13.65	22.58	PE	Blue
LV 02-2	23092TL-Bottle 006.d	14.68	27.24		
LV 02-3	23092TL-Bottle 007.d	26.77	57.16		
LV 02-4	23092TL-Bottle 008.d	23.38	55.93		
LV 04-1	23092TL-Bottle 013.d	ND	ND	PP	Pink
LV 04-2	23092TL-Bottle 014.d	ND	ND		
LV 04-3	23092TL-Bottle 015.d	0.19	10.07		
LV 04-4	23092TL-Bottle 016.d	6.58	20.54		
LV 07-1	23092TL-Bottle 021.d	ND	ND	PP	Clear
LV 07-2	23092TL-Bottle 022.d	ND	ND		
LV 07-3	23092TL-Bottle 023.d	ND	11.99		
LV 07-4	23092TL-Bottle 024.d	ND	11.57		
LV 08-1	23092TL-Bottle 025.d	ND	ND	PP	Blue
LV 08-2	23092TL-Bottle 026.d	ND	ND		
LV 08-3	23092TL-Bottle 027.d	3.05	14.44		
LV 08-4	23092TL-Bottle 028.d	0.00	22.97		
CZ 01-1	23092TL-Bottle 029.d	ND	ND	PP	Black
CZ 01-2	23092TL-Bottle 030.d	ND	ND		
CZ 01-3	23092TL-Bottle 031.d	ND	12.53		
CZ 01-4	23092TL-Bottle 032.d	ND	20.15		
CZ 02-1	23092TL-Bottle 033.d	ND	ND	PP	Pink
CZ 02-2	23092TL-Bottle 034.d	ND	ND		
CZ 02-3	23092TL-Bottle 035.d	ND	4.97		
CZ 02-4	23092TL-Bottle 036.d	10.86	29.93		
CZ 03-1	23092TL-Bottle 037.d	ND	ND	PP	Pink
CZ 03-2	23092TL-Bottle 038.d	ND	ND		
CZ 03-3	23092TL-Bottle 039.d	ND	7.68		
CZ 03-4	23092TL-Bottle 040.d	ND	3.82		

SAMPLE ID	LC-MS DATE FILE	DAY 1 (NG/ML)	DAY 10 (NG/ML)	MATERIAL (IR)	COLOR
CZ 05-1	23092TL-Bottle 045.d	ND	ND	PP	Clear
CZ 05-2	23092TL-Bottle 046.d	ND	ND		
CZ 05-3	23092TL-Bottle 047.d	ND	9.13		
CZ 05-4	23092TL-Bottle 048.d	5.36	25.13		
CZ 06-1	23092TL-Bottle 049.d	ND	ND	PE	Blue
CZ 06-2	23092TL-Bottle 050.d	ND	ND		
CZ 06-3	23092TL-Bottle 051.d	7.91	18.39		
CZ 06-4	23092TL-Bottle 052.d	11.67	30.28		
CZ 08-1	23092TL-Bottle 057.d	ND	ND	PE	Black
CZ 08-2	23092TL-Bottle 058.d	ND	ND		
CZ 08-3	23092TL-Bottle 059.d	2.94	20.47		
CZ 08-4	23092TL-Bottle 060.d	5.73	20.65		
DK 01-1	23092TL-Bottle 061.d	ND	ND	PE	Blue
DK 01-2	23092TL-Bottle 062.d	ND	ND		
DK 01-3	23092TL-Bottle 063.d	6.97	16.07		
DK 01-4	23092TL-Bottle 064.d	3.81	14.81		
DK 03-1	23092TL-Bottle 069.d	ND	ND	PE	Pink
DK 03-2	23092TL-Bottle 070.d	ND	ND		
DK 03-3	23092TL-Bottle 071.d	12.85	25.43		
DK 03-4	23092TL-Bottle 072.d	17.56	30.73		
DK 06-1	23092TL-Bottle 081.d	ND	ND	PP	Blue-green
DK 06-2	23092TL-Bottle 082.d	ND	ND		
DK 06-3	23092TL-Bottle 083.d	ND	ND		
DK 06-4	23092TL-Bottle 084.d	ND	5.53		
DK 07-1	23092TL-Bottle 085.d	ND	ND	PE	White
DK 07-2	23092TL-Bottle 086.d	ND	ND		
DK 07-3	23092TL-Bottle 087.d	1.22	12.05		
DK 07-4	23092TL-Bottle 088.d	5.46	14.62		
DK 08-1	23092TL-Bottle 089.d	ND	ND	PE	Red
DK 08-2	23092TL-Bottle 090.d	ND	ND		
DK 08-3	23092TL-Bottle 091.d	ND	ND		
DK 08-4	23092TL-Bottle 092.d	12.87	19.01		

SAMPLE ID	LC-MS DATE FILE	DAY 1 (NG/ML)	DAY 10 (NG/ML)	MATERIAL (IR)	COLOR
ESP 01-1	23092TL-Bottle 093.d	ND	ND	PE	Yellow
ESP 01-2	23092TL-Bottle 094.d	ND	ND		
ESP 01-3	23092TL-Bottle 095.d	7.74	25.41		
ESP 01-4	23092TL-Bottle 096.d	11.37	27.49		
ESP 02-1	23092TL-Bottle 097.d	ND	ND	PP	Blue
ESP 02-2	23092TL-Bottle 098.d	ND	ND		
ESP 02-3	23092TL-Bottle 099.d	ND	4.13		
ESP 02-4	23092TL-Bottle 100.d	10.44	16.05		
ESP 05-1	23092TL-Bottle 109.d	ND	ND	PP	Green
ESP 05-2	23092TL-Bottle 110.d	ND	ND		
ESP 05-3	23092TL-Bottle 111.d	ND	3.48		
ESP 05-4	23092TL-Bottle 112.d	ND	3.13		
NL 01-1	23092TL-Bottle 125.d	ND	ND	PP	Magenta
NL 01-2	23092TL-Bottle 126.d	ND	ND		
NL 01-3	23092TL-Bottle 127.d	ND	ND		
NL 01-4	23092TL-Bottle 128.d	ND	5.58		
NL 02-1	23092TL-Bottle 129.d	ND	ND	PP	Pink
NL 02-2	23092TL-Bottle 130.d	ND	ND		
NL 02-3	23092TL-Bottle 131.d	1.40	7.51		
NL 02-4	23092TL-Bottle 132.d	8.69	15.99		
NL 04-1	23092TL-Bottle 137.d	ND	ND	PP	Yellow
NL 04-2	23092TL-Bottle 138.d	ND	ND		
NL 04-3	23092TL-Bottle 139.d	8.34	8.74		
NL 04-4	23092TL-Bottle 140.d	8.53	10.28		
NL 08-1	23092TL-Bottle 153.d	ND	ND	PE	Green
NL 08-2	23092TL-Bottle 154.d	ND	ND		
NL 08-3	23092TL-Bottle 155.d	1.86	8.21		
NL 08-4	23092TL-Bottle 156.d	8.42	12.94		

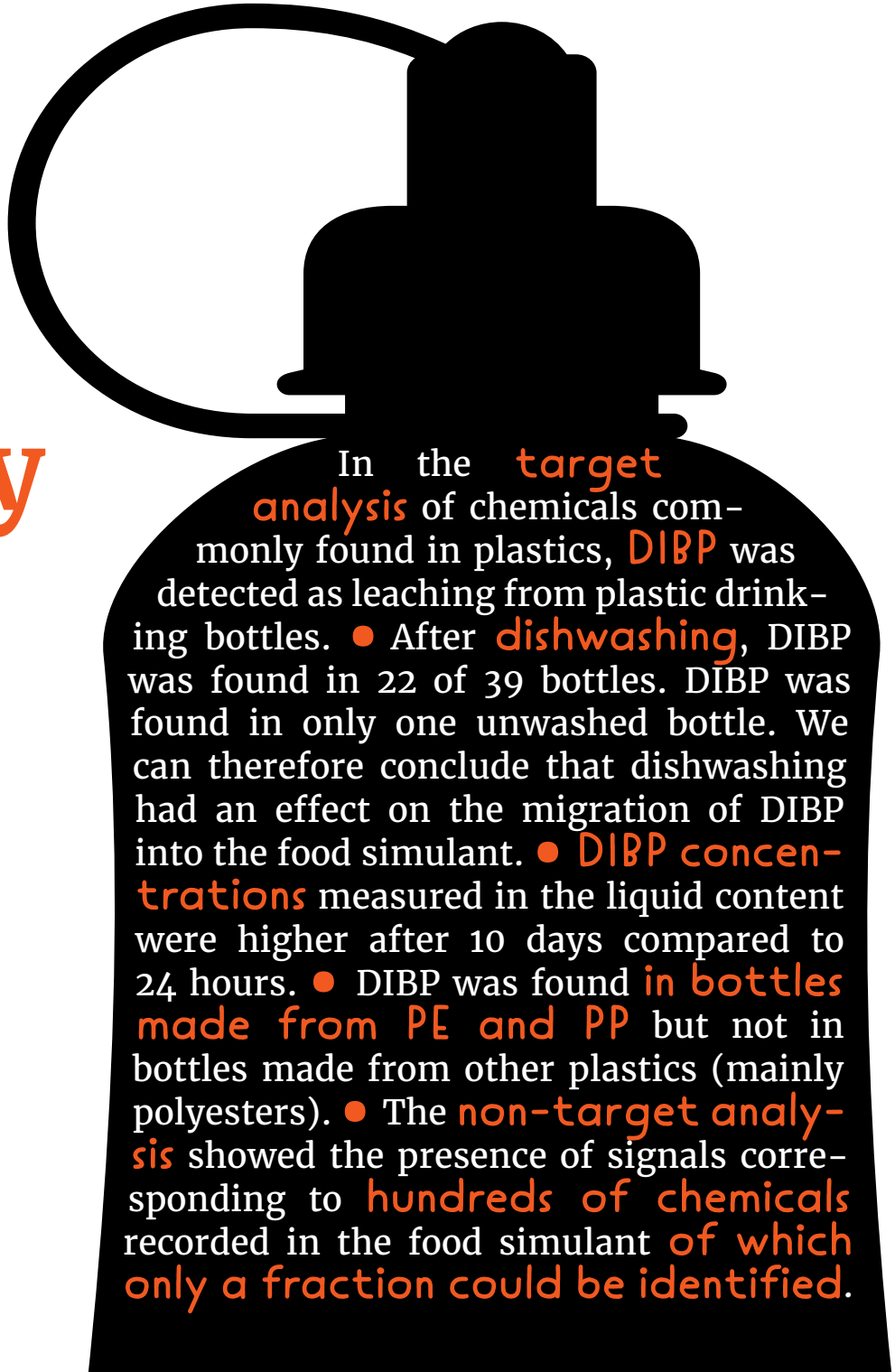
Note: Orange color indicates washed samples, black color indicates unwashed samples.
ND: not detected. LV: Latvia. CZ: Czech Republic. DK: Denmark. ESP: Spain. NL: Netherlands.

NON-TARGET ANALYSIS

Non-target analysis was deployed to assess if **any other chemicals** were also leaching into the food simulant, particularly after multiple cycles of dishwashing. The results showed the presence of signals corresponding to **hundreds of chemicals**. Several of these signals could be identified as known **plastic-related compounds**. The presence of Dibutylamine, Dibutyl maleate, Octadecanamide, N-Lauryldiethanolamine, and Tributyl citrate could be confirmed. However, only **a small fraction** of the hundreds of chemicals that were recorded in the food simulant **could be identified**. The rest of the detected signals represent **unknown chemicals** that could not be identified, even though McGill University searched several chemical libraries containing thousands of known substances.

Only a small fraction of the hundreds of chemicals that were recorded could be identified.

Summary of the main findings



In the target analysis of chemicals commonly found in plastics, DIBP was detected as leaching from plastic drinking bottles. ● After dishwashing, DIBP was found in 22 of 39 bottles. DIBP was found in only one unwashed bottle. We can therefore conclude that dishwashing had an effect on the migration of DIBP into the food simulant. ● DIBP concentrations measured in the liquid content were higher after 10 days compared to 24 hours. ● DIBP was found in bottles made from PE and PP but not in bottles made from other plastics (mainly polyesters). ● The non-target analysis showed the presence of signals corresponding to hundreds of chemicals recorded in the food simulant of which only a fraction could be identified.

Our main concerns

DIBP IN FOOD CONTACT MATERIALS: A REGULATORY GAP?

Of the chemicals detected in the food simulant, the concentrations of DIBP were the highest. **DIBP is a substance of very high concern (SVHC) and is classified as toxic to reproduction and an endocrine disruptor according to the European Chemicals Agency (ECHA).**

According to the latest amendment (2023/1442) of the Plastics FCM Regulation (10/2011), **DIBP use "is not authorised as an additive for plastic FCM**, but may be present in smaller amounts therein as an impurity or as a consequence of its use as a technical support agent in the manufacturing process of certain types of plastic". It is possible that the DIBP found in the PE and PP bottles originate from the catalyst mixture used in the production of these types of plastic.

In the same EU regulation, it is stated that the specific migration limit (SML) for the phthalates group (DBP+BBP+DEHP+DIBP) is 0.6 mg/kg (600 µg /kg). **Although we did not find concentrations higher than this group SML – hence producers of plastic bottles did not exceed any legal limits** – we are still deeply concerned about the presence of a substance of very high concern in 22 of 39 bottles. This is especially concerning since DIBP has been detected in many other consumer articles, such as plastic products, toys, children's clothing, and carpets. Exposure of children is demonstrated by the fact that DIBP and other phthalates have been detected in the urine of children in the EU.

Finally, in the latest amendment to the Plastics FCM regulation it is stated that **"DIBP substantially adds to the overall exposure and risk to consumers from phthalates and that such exposure together with its potency with regard to reproductive effects should also be taken into account by the risk manager."**

UNIDENTIFIED CHEMICALS

Only a fraction of the hundreds of chemical signals detected in the food simulants could be identified. For the chemicals that *could* be identified after the **non-target analysis**, such as Dibutylamine and Octadecanamide, very little safety data are available. This is a cause for concern as it means that children are exposed to hundreds of chemicals for which no or very little safety data are known.

DISHWASHING AFFECTS CHEMICAL MIGRATION

Our study and one previous study indicate that **dishwashing** has an effect on the release of chemicals. It would appear that dishwashing wears down the plastic and thereby increases leaching.

Recommendations

FOR REGULATORS

DIBP is not authorized for intentional use in plastic food contact materials, but since its use in the production of plastics is so common, its migration from plastics into food in low concentrations is legally accepted. This is a regulatory gap. Since DIBP is a substance of very high concern and there are many different and simultaneous exposure routes for children, **we urge the European Commission to end this unclear and undesirable situation by placing and enforcing a total ban on DIBP in plastics.** This will stimulate producers to better follow the current law, prevent DIBP contamination (including that of recycled materials), and use existing alternatives to protect the health of children.

The current study also suggests that adequate detection of chemicals and their migration over time in reusable food and beverage containers may be overlooked by current regulatory testing requirements. **We therefore urge the European Commission to adapt migration testing of repeated use FCMs to reflect the realistic daily routines of reusable plastics** (including many cycles of cleaning/dishwashing), with requirements for tests to be performed on the final article until it has reached its maximum life span and a focus on material stability over time.

FOR CONSUMERS

We advise consumers to **exercise caution when using plastics**, especially when it comes to children.

1. **Use as little plastic as possible**; especially for storing and warming up food or drinks.
2. **Opt for stainless steel.** Glass is also a good choice, but probably less practical for small children.

If you choose to continue using plastic drinking bottles for the time being:

3. **Do not use plastic water bottles for milk.** Milk contains fat and it is likely that more chemicals will migrate into fatty foods than into water.
4. **Refresh the water** in the bottle regularly.
5. **Wash the bottle by hand** instead of putting it in the dishwasher.

FOR PRODUCERS

We urge plastics producers to substitute the use or avoid the presence of DIBP to make their materials safer.

This project is a joint collaboration between the following organizations

TEGENGIF

Tegengif - Erase all Toxins (the Netherlands) is a not-for-profit organization based in Amsterdam. Our goal is a non-toxic living environment. We raise public awareness of consumers' producing appealing research, campaigning and influencing policy. We believe that increased awareness will both stimulate demand for toxin-free products and increase public support for regulations leading to a toxin-free world.

tegengif.nl

FORBRUGERRÅDET TÆNK

Forbrugerrådet Tænk is an independent Danish consumer organization, founded in 1947, which works on the promotion of sustainable and socially responsible consumption. Forbrugerrådet Tænk is the oldest consumer organization in Europe. It defends consumer rights and makes consumers a force in the market. Through chemical testing and communication to consumers, the initiative Forbrugerrådet Tænk Kemi specifically helps consumers to avoid problematic chemicals when shopping.

taenk.dk/kemi

ARNIKA

Arnika Association, based in the Czech Republic, is a non-governmental organization founded in 2001. Dedicated to safeguarding nature and ensuring a healthy environment for future generations, Arnika operates both domestically and internationally. From its inception, the organization has focused on protecting consumers from harmful chemicals in products, waste and environment. Recently, Arnika has expanded its efforts by conducting research on persistent organic pollutants and endocrine disruptors in various products.

arnika.or

ZERO WASTE EUROPE

Zero Waste Europe (ZWE) is the European network of communities, local leaders, experts, and change agents working towards a better use of resources and the elimination of waste in our society. We advocate for sustainable systems; for the redesign of our relationship with resources; and for a global shift towards environmental justice, accelerating a just transition towards zero waste for the benefit of people and the planet.

zerowasteeurope.eu

ZERO WASTE LATVIJA

Zero Waste Latvija is an NGO focused on promoting waste reduction and circular economy policies in Latvia. We do this through our work with decision-makers, education and raising public awareness.

zerowastelatvija.lv

REZERO

Rezero is a not-for-profit organization based in Barcelona and in Majorca. We create knowledge and promote innovative ideas, regulations and projects so that both companies, public administrations and citizens can have the opportunity to enjoy a model of production and consumption towards Zero Waste, without toxic materials or products that are left without use.

rezero.cat/en

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