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MARKET ANALYSIS: SPECIFIC MIGRATION OF METALS FOR REUSABLE PACKAGING MATERIALS

EXECUTIVE SUMMARY



Reusable plastic food packaging is widely available on the European market and increasingly used by consumers as an alternative to single-use materials. These products are often sold empty through retail channels with limited or unclear instructions regarding their intended use, temperature resistance, or suitability for contact with different types of food. As a result, consumers may use these materials under conditions that were not explicitly defined by the manufacturer, such as contact with hot or acidic foods or repeated reheating.

Under European legislation, plastic materials intended for food contact must comply with Commission Regulation (EU) No 10/2011, which establishes specific migration limits for substances, including metals and metalloids listed in Annex II. Compliance must be demonstrated not only for initial use, but also for repeated use when materials are intended to be reused.

EXECUTIVE SUMMARY



This white paper presents a market analysis conducted by Pack-Lab L.P. on twelve reusable plastic food contact materials purchased from retail stores in Greece and originating from different countries. The study focused on the specific migration of 23 metals regulated under Annex II of Regulation (EU) No 10/2011. Migration testing was carried out using 3% acetic acid as a food simulant, representing a worst-case scenario for metal migration.

Testing was performed according to the accredited methods *EN 13130-1:2004* for specific migration testing and *EN ISO 11885:2009* for elemental determination by ICP-OES. Incubation conditions were selected based on declared instructions for use or, where instructions were absent, on reasonably foreseeable consumer use. Two contact scenarios were applied: up to two hours at 70°C and up to thirty minutes at 40°C.

To simulate repeated consumer use, each material underwent three consecutive migration tests with handwashing before each use. Compliance was assessed based on the migration result of the third test cycle and its trend relative to the first two cycles, in accordance with the requirements for repeated-use articles under Regulation (EU) No 10/2011.

The results provide insight into the compliance of reusable plastic food containers currently available on the market and highlight the importance of clear usage instructions, appropriate material selection, and verification of safety under realistic conditions of use. This study contributes to a better understanding of metal migration behavior in reusable plastic packaging and supports informed decision-making by manufacturers, regulators, and other stakeholders in the packaging sector.

**The findings presented in this white paper are the result of internal research conducted at Pack-Lab, relying on proprietary methods developed and validated in-house.*

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1 INTRODUCTION: REUSABLE PLASTIC PACKAGING ON THE CONSUMER MARKET

1.1 Widespread Availability of Reusable Plastic Food Containers

Reusable plastic food packaging is now a standard product category across the European market. Consumers can easily purchase empty containers intended for repeated food contact from a wide range of retail environments, including large household goods sections, general merchandise stores, and smaller local shops. These products are often positioned as durable, convenient and environmentally preferable alternatives to single-use packaging.

1.2 Limited Consumer Information and Labeling Practices

Despite their widespread availability, the level of technical information provided to consumers is frequently limited. Many products are sold with minimal labeling, often restricted to basic symbols or short statements such as “food safe” or “suitable for reuse.” Clear guidance on critical parameters such as maximum contact temperature, suitability for hot food, microwave use, or compatibility with acidic contents is often absent.

In some cases, containers are visually indistinguishable from one another, even though their material composition and performance under heat or chemical stress may differ significantly.

1.3 Consequences of Unclear Instructions for Consumer Use

As a result, consumers commonly rely on assumptions when using these materials. A container purchased for cold storage may be used for hot meals, reheating, or prolonged contact with acidic foods, simply because no restrictions are communicated. Over repeated use cycles, including washing and exposure to elevated temperatures, the material may undergo changes that affect its migration behavior.

1.4 Importance of Foreseeable Use in Food Contact Safety

From a food safety perspective, this gap between product availability and user information is significant. Regulation (EC) No 1935/2004 and Commission Regulation (EU) No 10/2011 require that materials placed on the market are safe under normal or foreseeable conditions of use. When instructions are incomplete or missing, the definition of “foreseeable use” becomes particularly important and places greater emphasis on analytical verification.



2 REGULATORY BACKGROUND

2.1 European Framework for Plastic Food Contact Materials

Plastic materials and articles intended to come into contact with food are regulated at European level under Commission Regulation (EU) No 10/2011. This regulation establishes requirements regarding composition, permitted substances, migration limits, and compliance testing for plastic food contact materials.

2.2 Migration Limits and Consumer Protection Principles

One of the core principles of the regulation is that substances must not migrate into food in quantities that could endanger human health or bring about an unacceptable change in food composition. To support this principle, the regulation defines overall migration limits as well as specific migration limits (SMLs) for certain substances.

2.3 Metals and Metalloids Restricted Under Annex II

Annex II of Regulation (EU) No 10/2011 specifically addresses restrictions on the migration of metals and metalloids (Table 2.3.1). These elements may be present in plastics due to their use as catalysts, stabilizers, pigments, fillers, or as impurities introduced during manufacturing. The regulation assigns maximum permitted migration values for each listed element, expressed as mg/kg of food or food simulant.

The metals listed in Annex II include both essential elements, such as iron and zinc, and toxic elements, such as lead and cadmium, reflecting different toxicological concerns and exposure thresholds.

2.4 Compliance Testing and Repeated-Use Requirements

Compliance with Annex II is typically demonstrated through specific migration testing using appropriate food simulants and test conditions. For reusable materials, the regulation requires that compliance be demonstrated after repeated use, not only at first contact.

Table 2.3.1 - Metals Subject to Specific Migration Limits According to Annex II of Regulation (EU) No 10/2011

No.	Metal	Specific Migration Limit (mg/kg of food)
1	Aluminum (Al)	1
2	Arsenic (As)	0,01
3	Barium (Ba)	1
4	Calcium (Ca)	60
5	Cadmium (Cd)	0,002
6	Cobalt (Co)	0,05
7	Chromium (Cr)	0,01
8	Copper (Cu)	5
9	Europium (Eu)	0,05
10	Iron (Fe)	48
11	Gadolinium (Gd)	0,05
12	Mercury (Hg)	0,01
13	Potassium (K)	60
14	Lanthanum (La)	0,05
15	Lithium (Li)	0,6
16	Magnesium (Mg)	60
17	Manganese (Mn)	0,6
18	Sodium (Na)	60
19	Nickel (Ni)	0,02
20	Lead (Pb)	0,01
21	Antimony (Sb)	0,04
22	Terbium (Tb)	0,05
23	Zinc (Zn)	5

3 SCOPE OF STUDY AND SAMPLE SELECTION

3.1 Objectives of the Market Analysis

The objective of the present study was to assess whether reusable plastic food contact materials available on the retail market comply with the specific migration limits for metals set out in Regulation (EU) No 10/2011. Particular emphasis was placed on repeated use and on the suitability of the materials under their stated or reasonably foreseeable conditions of use.

3.2 Selection of Market Samples

A total of twelve reusable plastic food contact materials were selected for analysis. The samples were purchased directly from retail stores in Greece to reflect products available to consumers. The selection included a range of container types, sizes, and apparent material qualities, as well as products originating from different countries, including Greece, China, and India. Images of the selected samples are presented in sections 3.2.1 and 3.2.2.

3.3 Evaluation of Declared and Assumed Use Conditions

For each product, any instructions for use provided by the manufacturer were documented. Where such instructions were absent or incomplete, assumptions regarding use conditions were based on typical consumer behavior and common household practices.

This approach allowed the study to address not only formal compliance but also practical safety under real-world use scenarios.

3.2.1 - Photos of Samples included in The Study (1-6)

1



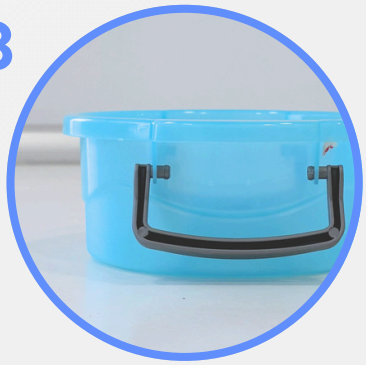
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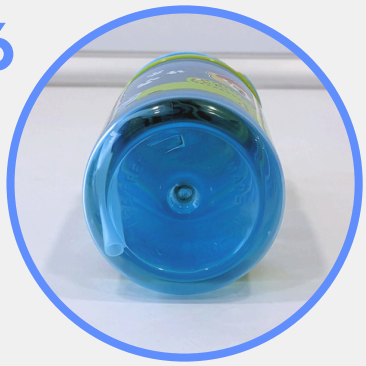
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3.2.2 - Photos of Samples Included in The Study (7-12)

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8



10



9



11



12



Table 3.3.1 - Samples Included in The Study

Sample	Material	Control Conditions (h/°C)	Country of Manufacture	What is referred to as heat treatment or hot food?	What is stated about foods that are allowed to come into contact?	Capacity
1	Tupperware PP	2/70	China	Microwave safe	Suitable for contact with food	800 ml
2	Tupperware PP	0,5/40	Greece	Not specified	A toast	Not specified
3	Tupperware PP	2/70	Greece	Microwave symbol only	Glass- fork symbol only	Not specified
4	Lemon Squeezer PP	0,5/40	Not specified	Not specified	Glass- fork symbol only	Not specified
5	Tupperware PP	0,5/40	Greece	Microwave symbol only	Suitable for contact with food	350 ml
6	Water bottle PP	0,5/40	China	Not suitable for microwave	Suitable for contact with water only	350 ml
7	Tupperware PP	2/70	Greece	Microwave symbol only	lunch box for a small meal	1,35 lt
8	Reusable knife-fork-spoon set	2/70	Not specified	Not specified	Not specified	-
9	Plastic cups PP	0,5/40	Greece	Not specified	Glass- fork symbol only	430 ml
10	Reusable plastic cup PE	2/70	China	suitable for heating food, but it is recommended not to do so	Suitable for contact with beverages and food	Not specified
11	Reusable knife-fork-spoon PE	2/70	India	Not suitable for microwave	Suitable for contact with food	-
12	Reusable plastic straws PP	2/70	Not specified	Max 70°C for washing	Glass- fork symbol only	-

4 SAMPLE PREPARATION AND FOOD SIMULANTS

4.1 Sample Preparation

Sample preparation depends on the geometry of each rigid plastic article.

Hollow articles intended to contain food (e.g., containers, cups, bottles) were tested in their final commercial form. No cutting was required, as the internal surfaces represent the food-contact area.

For solid articles without a defined cavity (e.g., cutlery, straws), representative specimens were prepared when necessary to allow complete exposure of the food-contact surfaces.

All samples were handled under controlled laboratory conditions prior to migration testing.

4.2 Food Simulant Addition and Sealing

At the next stage, the selected food simulant was applied according to the exposure configuration of each article. In this study, **simulant B (3% w/v acetic acid)** was used. This simulant is commonly applied for acidic foodstuffs and is considered to represent a worst-case scenario for metal migration from plastic materials, in line with *Joint Research Centre* (JRC) migration testing guidelines.



5 INCUBATION AND CONTACT SCENARIOS

5.1 Incubation

Migration testing was performed using either **article filling** or **total immersion** methods, depending on the article type.

Hollow articles were filled with simulant B, as previously mentioned, up to their intended capacity and placed in a temperature-controlled oven. The articles were covered to prevent evaporation during incubation. Solid articles were fully immersed in the same simulant within inert plastic vessels and incubated under identical temperature-controlled conditions.

The incubation conditions applied in this study were selected based on the instructions for use provided by the manufacturers of the tested materials. Where instructions were available, the declared maximum temperatures and contact times were used to define the test parameters.

In cases where no instructions for use were provided, incubation conditions were selected based on the expected and reasonably foreseeable use of the materials by consumers. This approach reflects the regulatory requirement that materials must be safe under normal or foreseeable conditions of use.

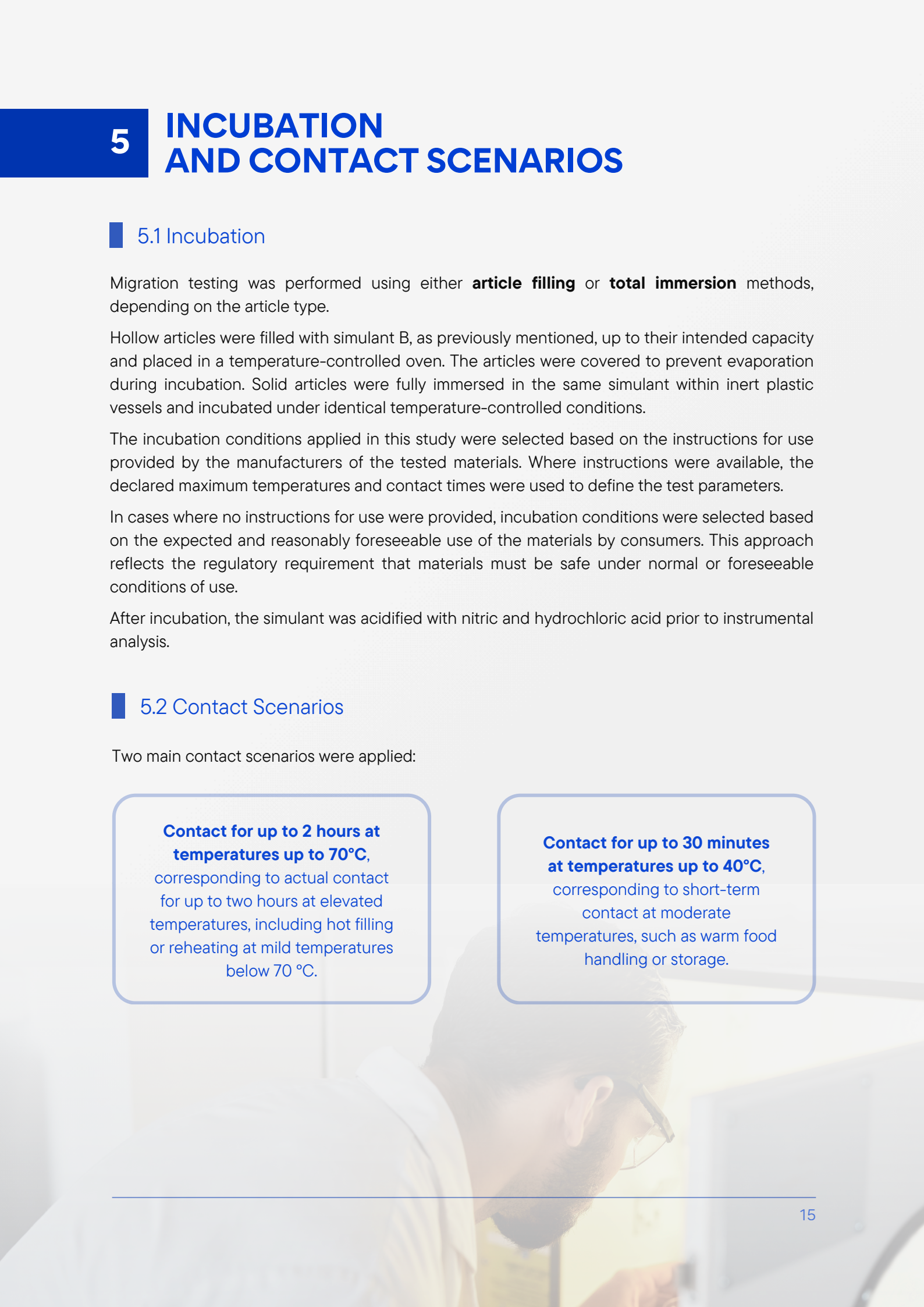
After incubation, the simulant was acidified with nitric and hydrochloric acid prior to instrumental analysis.

5.2 Contact Scenarios

Two main contact scenarios were applied:

Contact for up to 2 hours at temperatures up to 70°C, corresponding to actual contact for up to two hours at elevated temperatures, including hot filling or reheating at mild temperatures below 70 °C.

Contact for up to 30 minutes at temperatures up to 40°C, corresponding to short-term contact at moderate temperatures, such as warm food handling or storage.



6 SPECIFIC MIGRATION ANALYSIS: INTRUMENTATION, REPEATABILITY AND EVALUATION OF ANALYSIS



6.1 Specific Migration Analysis

The acidified simulants are then transferred to the autosampler of an inductively coupled plasma optical emission spectrometer (ICP-OES). Prior to analysis, standard solutions are prepared and calibration curves are generated for each metal. During measurement, the liquid simulant is introduced into the plasma, where the migrated metals are detected and quantified based on their characteristic emission signals.

6.2 Instrumentation: ICP-OES

The determination of migrated metals was carried out using inductively coupled plasma optical emission spectrometry (ICP-OES), in accordance with *EN ISO 11885:2009*.

All analyses were performed using an ICP-OES instrument manufactured by Agilent Technologies (model 5800). The instrument was operated under validated conditions, suitable for the determination of trace elements in acidic aqueous matrices.

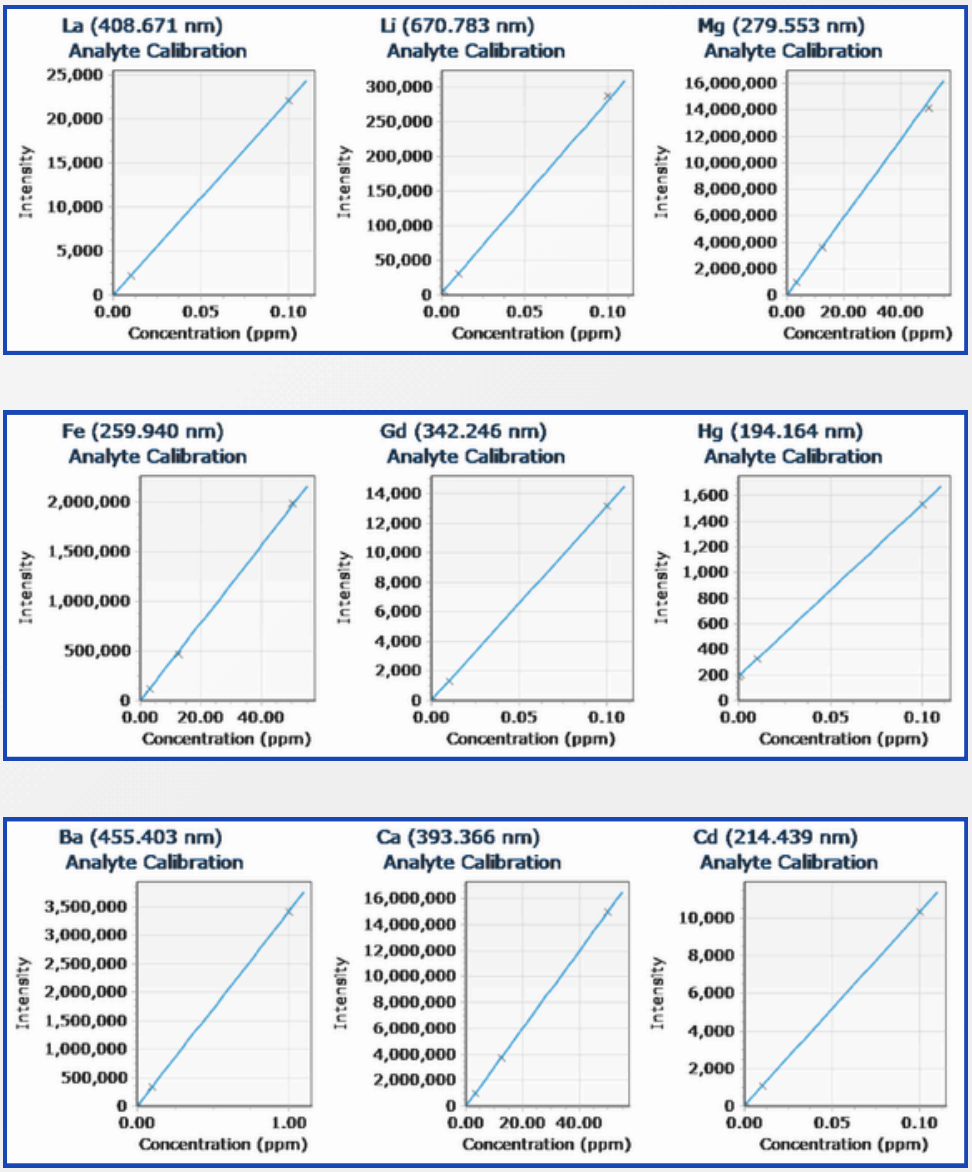


6.3 Calibration and Repeatability

Calibration curves were prepared individually for each of the 23 metals regulated under Annex II of Regulation (EU) No 10/2011. Certified standard solutions were used, and calibration was performed prior to each testing day to ensure accuracy and repeatability.

Each simulant extract was analyzed three times to confirm analytical consistency and reliability of the results.

6.3.3 Examples of calibration curves in an ICP-OES instrument



6.4 Testing Approach

As the investigated materials are intended for repeated use, specific migration testing was performed over three consecutive test cycles for each sample.

Before each migration test, the sample was subjected to simple hand washing using mild detergent and water, simulating typical consumer cleaning practices. No aggressive cleaning agents or mechanical abrasion were applied.

The same incubation and analytical conditions were used for all three test cycles to **ensure comparability of results**.

6.5 Evaluation Criteria and Compliance Assessment

Migration results were calculated using the **real surface-to-volume ratio (S/V ratio, expressed in dm²/kg)** corresponding to the geometry of each container. This ratio was applied consistently throughout the study rather than using the conventional default ratio of 6 dm2/kg provided in (EC) 10/2011.
For each metal, compliance with Regulation (EU) No 10/2011 was assessed based on the following criteria:

1. The migration result obtained from the **third test cycle** must be below the specific migration limit defined in Annex II of the regulation.

2. The migration result of the third test cycle must be **lower than the results of the first and second cycles**, demonstrating decreasing migration with repeated use.

Only materials fulfilling both criteria were considered compliant for repeated food contact under the tested conditions.

6.6 Applicability to Other Plastics

A similar preparation and testing approach can be applied to other plastic food contact materials, such as rigid containers and bottles, with appropriate adaptations to sample preparation and contact geometry.

7 RESEARCH RESULTS

7.1 Evaluation of Migration Results Against Legal Limits

Migration results were calculated using the real surface-to-volume ratio applicable to each sample. The amount of each metal migrated into the food simulant was compared with the corresponding specific migration limit.

Table 7.1.1 - List of Samples Included in the Study

Sample	Material	Analysis time (h)	Analysis temperature (∘C)	Elements in compliance after multiple use of the material	Elements out-of-compliance after multiple use of the material	Compliance for multiple use of material according to written instructions or expected intended use.
1	Tupperware PP	2	70	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
2	Tupperware PP	0,5	40	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
3	Tupperware PP	2	70	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
4	Lemon Squeezer PP	0,5	40	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
5	Tupperware PP	0,5	40	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
6	Water bottle PP	0,5	40	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
7	Tupperware PP	2	70	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
8	Reusable knife-fork-spoon set	2	70	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
9	Plastic cups PP	0,5	40	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
10	Reusable plastic cup PE	2	70	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
11	Reusable knife-fork-spoon PE	2	70	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS
12	Reusable plastic straws PP	2	70	Al,As,Ba,Ca,Cd,Co,Cr,Cu, Eu,Fe,Gd,Hg,K,La,Li,Mg, Mn,Na,Ni,Pb,Sb,Tb,Zn	-	PASS

8 CONCLUSION

8.1 Regulatory Compliance Under Conservative Conditions

This market assessment evaluated the specific migration of 23 metals from reusable rigid plastic food contact materials available on the Greek market. Testing was conducted using conservative conditions designed to reflect worst-case acidic contact and repeated use scenarios.

All analyzed samples complied with the specific migration limits established under Regulation (EU) No 10/2011 for the tested conditions. Migration values obtained during the third consecutive test cycle remained below the applicable legal limits and did not exceed results from previous cycles. Based on these findings, the tested materials meet regulatory requirements for repeated food contact under the defined conditions.

8.2 Implications for Consumer Safety

The results indicate that, when used under the tested conditions, the investigated articles do not pose a risk related to metal migration. The application of a worst-case simulant and controlled time–temperature combinations provides additional assurance that consumer exposure remains within safe limits.

These findings support the effectiveness of the current European regulatory framework when properly implemented throughout the supply chain.

8.3 Observations on Market Practices

While compliance was demonstrated across all samples, variability was observed in the clarity and completeness of product instructions. In some cases, labeling did not clearly define maximum temperature limits, suitability for reheating, or specific usage restrictions.

Although the materials themselves performed within legal thresholds, insufficient consumer guidance may increase the likelihood of use outside validated conditions. Since regulatory compliance is inherently linked to intended and foreseeable use, transparent labeling remains a critical component of product safety.

8.4 Recommendations for Manufacturers and Stakeholders

Manufacturers and distributors should ensure that product labeling clearly communicates the maximum recommended temperature, the suitability of the article for hot filling or reheating, the intended types of food contact, and the appropriate cleaning and reuse instructions. Providing complete and precise information helps prevent misuse outside validated conditions and strengthens overall consumer confidence in reusable food contact materials.

8.5 Final Statement

This study confirms that the tested reusable rigid plastic articles are compliant with applicable EU legislation and safe for food contact under the analyzed conditions. Continued adherence to regulatory testing requirements, combined with improved communication toward end users, will further enhance trust in reusable packaging systems and support their safe and sustainable use in the European market.

8.6 Future Scope

Specific migration of metals represents only one parameter for food contact compliance. For a material to be fully compliant, additional analyses are required, such as overall migration, specific migration of primary aromatic amines and organoleptic testing, which were out of scope of the present study and constitute subjects of future studies by Pack-Lab.



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ABOUT PACK-LAB

Pack-Lab Limited Partnership, established in 2019, is a specialized laboratory that offers analyses and consultanting, dedicated exclusively to the packaging industry. Our mission is to ensure consumer safety and product integrity through precise, reliable analysis and expert guidance on packaging materials.

Our state-of-the-art laboratory performs advanced chemical and technical analyses, with particular expertise in migration testing of plastics, multilayer laminates, and other food contact materials. Using accredited methods and instruments, including ICP-OES, we help manufacturers and users verify compliance with EU regulations 1935/2004 and 10/2011, including specific migration limits for metals and repeated-use safety requirements.

Founded by *Theodoros Paraskevopoulos*, a chemical engineer with a Master's in Packaging Technology and over a decade of industry experience, Pack-Lab combines technical expertise with practical consulting. Our team supports manufacturers, importers, and users of packaging materials, providing actionable insights to ensure safety, regulatory compliance, and product performance.

At Pack-Lab, we operate under core values of reliability, integrity, impartiality, trust, and respect, ensuring that all analyses and guidance are objective, confidential, and of the highest quality. This combination of scientific rigor and industry knowledge enables us to deliver results that not only meet regulatory standards but also enhance confidence in packaging materials across the supply chain.

Through our services, we empower the packaging industry to make informed decisions, improve product safety, and uphold consumer trust, reinforcing our commitment to excellence and transparency in every project we undertake.