

# Contents

Preface .....	1
1 Additive Migration from Plastics into Packaged Commodities .....	5
1.1 Introduction .....	5
1.2 Principles of Extractability Testing.....	5
1.3 Extractability Testing in the European Union .....	7
1.4 Extractability Testing in the UK.....	8
1.5 Extractability Testing in the USA .....	8
2 Types of Polymers Used in Commodity Packaging .....	13
2.1 Polyolefins and Copolymers.....	13
2.1.1 Polyethylene.....	13
2.1.2 Polyethylene Naphthalate .....	15
2.1.3 Polyethylene <i>co</i> -methacrylic Acid.....	15
2.1.4 Polypropylene .....	15
2.2 Polymethyl Pentene.....	16
2.3 Ethylene-vinyl Acetate Copolymers .....	16
2.4 Ionomers .....	16
2.5 Vinyl Plastics and Vinyl Copolymers .....	17
2.5.1 Polyvinyl Acetate .....	18
2.6 Polystyrene and its Copolymers .....	18
2.7 Polyacrylonitrile .....	19
2.8 Acrylic-based Multi Polymer Compounds .....	19

2.9	Lopac .....	19
2.10	Borex.....	20
2.11	Fluorocarbon Polymers.....	20
2.12	Polyamides .....	20
2.13	Acrylics .....	20
2.13.1	Polymethylmethacrylate.....	20
2.13.2	Polyethylene Terephthalate (Terylene).....	20
2.14	Polycarbonates .....	21
2.15	Polyacetals.....	21
2.16	Polyphenylene Oxide (PPO).....	22
2.17	Polysulfone.....	22
2.18	Thermosets.....	22
2.19	Phenol-formaldehyde.....	22
2.20	Urea-formaldehyde.....	23
2.21	Melamine-formaldehyde.....	23
2.22	Polyesters.....	23
2.23	Epoxy Resins .....	23
2.24	Polyurethanes .....	24
2.25	Silicones.....	24
2.26	Natural Polymers.....	24
2.26.1	Cellulose .....	24
2.26.2	Cellulose Derivatives.....	25
2.27	<i>p</i> -Hydroxybenzoic Acid and 2-Hydroxy-6-naphthoic Acid.....	26
2.28	Polymers Used in Gas Barrier Applications.....	26
2.28.1	Rubber and Elastomers.....	26

3	Non-Polymeric Components of Plastics .....	27
3.1	Polymerisation Residues .....	29
3.2	Residual and Unreacted Starting Materials .....	29
3.3	Polymerisation Medium.....	30
3.4	Catalyst Decomposition Agents .....	31
3.5	Other Impurities Introduced During Polymerisation.....	31
3.5.1	Chemicals Added During Polymerisation .....	31
3.6	Processing Aids.....	31
3.6.1	Antiblock Agents .....	32
3.6.2	Antioxidants .....	32
3.6.3	Antisplit Agents .....	32
3.6.4	Antistatic Agents.....	32
3.6.5	Heat Stabilisers .....	33
3.6.6	Lubricants.....	33
3.6.7	Melt Strength Improvers .....	34
3.6.8	Mould Release Agents.....	34
3.6.9	Plasticisers.....	34
3.6.10	Slip Additives .....	35
3.6.11	Other Stabilisers.....	35
3.7	End-Use Additives .....	35
3.7.1	Antiblock Additives .....	36
3.7.2	Antifungal agents.....	36
3.7.3	Antioxidants .....	36
3.7.4	Antistatic Agents.....	36
3.7.5	Bactericidal Agents.....	36
3.7.6	Brighteners and Whiteners .....	36
3.7.7	Colorants .....	37
3.7.8	Expanding Agents (Blowing Agents, Foaming Agents).....	37
3.7.9	Impact Improvers.....	38
3.7.10	Lubricants.....	38

3.7.11	Plasticisers.....	38
3.7.12	Ultraviolet Protective Agents.....	38
3.7.13	Ultraviolet Screens .....	39
3.7.14	Ultraviolet Degradation Inhibitors .....	39
3.7.15	Gas Barrier Packaging Oxygen Scavengers.....	39
4	Determination of Antioxidants.....	43
4.1	Santonox R (4,4'-thiobis-6- <i>tert</i> butyl <i>m</i> -cresol) in Aqueous and Non-aqueous Extractants .....	43
4.1.1	Method.....	43
4.2	DLTDP in Aqueous and Non-aqueous Extractants.....	45
(a)	Thin-Layer Chromatography.....	46
	Method.....	47
	Procedure.....	49
(b)	Infrared Spectroscopy .....	51
	Method.....	52
	Procedure.....	55
(c)	Oxygen Flash Combustion.....	58
	Comparison of Infrared and Oxygen Flask Results.....	60
4.3	Irganox 1076 (Octadecyl-3-(3,5-di- <i>t</i> -butyl-4-hydroxy phenyl propionate) in Non-aqueous Extractants.....	64
4.4	Ionox 330 (1,3,5-trimethyl-2,4,6-tris(3,5 di <i>tert</i> -butyl-4-hydroxybenzyl)benzene) Antioxidant in Fatty Extractants.....	65
4.5	Miscellaneous Antioxidants.....	68
5	Determination of Ultraviolet Stabilisers in Extractants.....	75
5.1	Uvitex OB (2,5-bis (5'- <i>tert</i> butyl-2-benzoxazolyl)thiophene) in Aqueous Extractants.....	75
6	Determination of Plasticisers in Extractants .....	81
6.1	Phthalates in Oily and Aqueous Extractants.....	81
6.1.1	Phthalate Platicisers in Fatty Extractants.....	81
6.1.2	Phthalates in Aqueous Alcoholic Extract.....	91

6.2	Phthalates and Adipates in Aqueous and Fatty Extractants .....	94
7	Determination of Organotin Thermal Stabilisers in Extractants .....	105
7.1	Organotin Compounds in Fatty Extractants .....	105
8	Determination of Organic Sulfur Compounds in Extractants .....	109
9	Determination of Polydimethyl Siloxanes in Extractants .....	119
9.1	Wine and Olive Oil.....	119
9.1.1	PDMS in Olive Oil and Wine.....	120
10	Determination of Lubricants in Extraction Liquids .....	125
11	Determination of Monomers and Oligomers in Extractants .....	129
11.1	Determination of Acrylonitrile in Aqueous and Fatty (Liquid Paraffin) Extractants .....	129
11.1.1	Determination of Acrylonitrile in Aqueous-ethanol Extractants.....	129
11.1.2	Determination of Acrylonitrile Monomer in Acidic and Alkaline Extractants.....	130
11.1.3	Determination of Acrylonitrile in 6% Hydrochloric Acid Extractant.....	131
11.1.4	Determination of Acrylonitrile Monomer in 5% Sodium Carbonate Extractant.....	131
11.1.5	Determination of Acrylonitrile in Light Liquid- Paraffin Extractant.....	133
11.1.6	Separation of Acrylonitrile from Light Liquid-Paraffin and n-Heptane Extractants .....	133
11.1.7	Determination of Acrylonitrile in Aqueous, Acidic and Alkaline Extractants.....	135
11.1.8	Determination of an Acrylonitrile in Aqueous Ethanol Extractant.....	136
11.1.9	Calculation of the Acrylonitrile Contents of the Extractants.....	136
11.2	Determination of Styrene Monomer and Aromatic Hydrocarbons in Aqueous and Fatty (Liquid Paraffin) Extractants.....	138

11.2.1	Determination of Styrene Monomer and Other Volatiles in Polystyrene.....	138
11.3	Determination of Acrylate Monomers and Oligomers in Aqueous and Fatty Extractants.....	141
12	Analysis of Polymer Extraction Liquids Containing More Than One Migrant.....	153
12.1	Preliminary Solvent Extraction of Gross Additives from Aqueous and Alcoholic Extractants.....	154
12.1.1	Extraction Test (Assuming the Extraction Test is Carried Out on 700/800 ml Scale) .....	154
12.1.2	Ether Extraction.....	155
12.2	Separation of Individual Additives from Solvent Extract of Extractant Liquid .....	155
(a)	Mixture of Santonox R, Ionol CP and DLTDP .....	155
12.2.1	Indirect Determination of Additives on the Thin-layer Plate.....	157
(b)	Mixture of Butylated Hydroxy Toluene (BHT) Antioxidant and 2-Hydroxy-4- <i>n</i> -octoxybenzophenone Light Stabiliser in Extractants .....	161
12.2.2	Scaling of Operations.....	162
12.3	Ether Extraction of Extraction Liquid .....	163
13	Determination of Additives and their Breakdown Products in Extractants.....	171
13.1	Determination of Lauric Diethanolamide and its Degradation Products in Aqueous Fatty Extraction Liquids.....	172
13.1.1	Determination of Lauric Diethanolamide and DEA in the Distilled Water Extractant.....	175
13.1.2	Determination of Lauric Diethanolamide and DEA in the Aqueous 5% Sodium Carbonate Extractant.....	176
13.1.3	Determination of Lauric Diethanolamide and DEA in the 50% <i>w/v</i> Aqueous Ethyl Alcohol Extractant.....	176
13.1.4	Determination of Lauric Diethanolamide and Hydrolysis Products in the 5% <i>w/v</i> Aqueous Citric Acid Extractant.....	180

13.1.5	Determination of Lauric Diethanolamide in the Liquid Paraffin Extractant.....	181
13.2	Polymeric Plasticisers.....	195
13.3	Polybutylene Adipate, Poly(1,2-Propylene Adipate) and Polybutylene Succinate .....	196
13.4	Organosulfur Vulcanising Agents .....	198
14	Additive Migration Theory.....	201
14.1	Polyethylene Naphthalate .....	218
14.2	The Total Migration Concept .....	248
15	Gas Barrier Properties of Food Packaging Plastic Films.....	259
16	Legislative Aspects of the Use of Additives in Packaging Plastics .....	273
16.1	Regulatory System in the European Union.....	273
16.2	The Regulatory System Existing in the UK .....	280
16.3	Regulatory System Existing in the USA.....	280
	FDA compliance for Ultraviolet Electron Beam (EB) Coatings and Adhesives.....	290
17	Direct Determination of Migrants from Polymers into Foodstuffs.....	297
17.1	Antioxidants.....	297
17.2	Plasticisers .....	301
17.2.1	Olive Oil.....	301
17.2.2	Vegetables.....	301
17.2.3	Meat.....	301
17.2.4	Miscellaneous Foods.....	302
17.2.5	Hydrocarbons.....	302
17.3	Organotin Compounds.....	302
17.4	Polyvinylpyrrolidone .....	303
17.5	Benzoic Acid.....	303

*Additive Migration from Plastics into Foods*

17.6 Alkyl Citrates .....	303
17.7 Metals .....	303
Abbreviations and Acronyms .....	309