

Trace element analysis of 59 plastic consumer products

Montserrat Filella

December 2018



**UNIVERSITÉ
DE GENÈVE**

Montserrat Filella, Department F.-A. Forel, University of Geneva,
Boulevard Carl-Vogt 66, CH-1205 Geneva, Switzerland
email: montserrat.filella@unige.ch

1. Objective

According to the "Contrat de mandat de service" and an "Avenant no. 1" signed between the Université de Genève and the Association suisse des exploitants d'installations de valorisation des déchets (ASED), 59 plastic consumer products were provided by the ASED and analysed by the University of Geneva (Montserrat Filella).

2. Methods

Samples were analysed by energy-dispersive FP-XRF using a Niton XL3t 950 He GOLDD+. The Niton XL3t employs a miniature X-ray tube with a silver transmission anode that operates at up to 50 kV of high voltage and 200 μ A of current and is fitted with a geometrically optimised large area silicon drift detector to detect fluorescent X-rays from the sample.

The XRF instrument was employed nose-upwards in a collapsible bench-top accessory stand (Thermo Scientific SmartStand, with internal dimensions of 20 cm \times 20 cm \times 10 cm; PN 420-017) and was connected to a laptop computer via USB. Samples were placed on the stainless steel base plate of the accessory stand above the detector window or, for samples smaller than the 8 mm window diameter, on to a SpectraCertified Mylar polyester 3.6 μ m film that was carefully positioned such that the sample lay centrally above the window. On closing the shield of the stand, measurements with appropriate thickness correction and collimation (3 mm or 8 mm beam width) were activated remotely through the laptop. For objects too large to be contained by the laboratory accessory stand, the XRF was used handheld.

The concentration of the chemical elements were determined in a 'plastics' mode through a standardless, fundamental parameters-based alpha coefficient correction model. This iterative approach accounts for background matrix effects by describing characteristic X-ray intensities using mathematical equations that tie together the physics of the interaction of X-rays with sample components, and has a wide dynamic range that is independent of the size and shape of the surface. Because plastics are composed of light elements that are weak absorbers and relatively strong scatterers of X-rays, below a critical thickness the measured intensity of characteristic X-rays will be

dependent on both the analyte concentration and the depth of the sample. In the plastics mode, the Niton XL3t incorporates a thickness correction algorithm down to 50 μm that employs a compensation for mass absorption based on Compton scatter so that variations in density are factored in. Although the corrective algorithm is embedded in the fundamental parameters code and inaccessible to the user, it has been empirically defined for a number of elements and in a variety of plastics elsewhere. In the present study, sample thickness was determined through the flattest or smoothest ('measurement') surface using 300 mm Allendale digital callipers, and to increase the effective depth and flatness of thin or hollow samples analysed in the accessory stand, items were cut (with scissors, pliers or a blade), folded or layered. The corrective algorithm was employed for all samples whose measured thickness was <30 mm.

Measurements were performed as follows. An initial, ~ 2 -second matrix evaluation based on the measurement of characteristic chlorine peaks (and defining PVC as Cl N 15% by weight) was succeeded by an analysis time of between 60 and 200 s, comprising counting periods equally distributed between a low energy range (20 kV and 100 μA) and main energy range (50 kV and 40 μA). Spectra were quantified by fundamental parameter coefficients to yield elemental concentrations on a dry weight basis (in ppm) and with a counting error of 2σ (95% confidence).

Polyethylene reference discs supplied by the manufacturer and certified for the elements of interest were analysed at the beginning and end of each one hour sample measurement session.

Indicative limits of detection are: 5-10 ppm for arsenic, bromine, chromium, lead and mercury; 50-100 ppm for antimony, cadmium, copper, nickel and zinc. However the detection limits in XRF depend on the sample thickness and are often much better than the ones mentioned here. In particular, the detection limit of cadmium can be less than 10 ppm for samples thicker than 13 mm by increasing the measuring time.

3. Results

The 50 objects initially sent by the ASED were analysed (total number of analysis: 63 since many of the objects were composite). The list and pictures of the objects as

sent are shown in Annexes 1 and 2. Results are shown first ordered by object, accompanied by a picture of the corresponding object, as requested by the ASED, and, secondly, classified by chemical element. The original numbering has been kept. Later, a second set of 9 objects were sent. These results are shown separately.

3.1 Results classified by objects

1		Black flip flop	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Ti</td> <td>542 ± 34</td> </tr> <tr> <td>Sn</td> <td>2219 ± 77</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Ti	542 ± 34	Sn	2219 ± 77				
Element	Concentration (ppm)												
Ti	542 ± 34												
Sn	2219 ± 77												
2		Green shoe	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Zn</td> <td>5584 ± 148</td> </tr> <tr> <td>Cu</td> <td>48.8 ± 28.1</td> </tr> <tr> <td>Ti</td> <td>16682 ± 322</td> </tr> <tr> <td>Ba</td> <td>1501 ± 304</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Zn	5584 ± 148	Cu	48.8 ± 28.1	Ti	16682 ± 322	Ba	1501 ± 304
Element	Concentration (ppm)												
Zn	5584 ± 148												
Cu	48.8 ± 28.1												
Ti	16682 ± 322												
Ba	1501 ± 304												
3		Blue bottle	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Cu</td> <td>49.0 ± 7.6</td> </tr> <tr> <td>Ni</td> <td>11.0 ± 5.8</td> </tr> <tr> <td>Ti</td> <td>223 ± 9</td> </tr> <tr> <td>Ba</td> <td>399 ± 228</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Cu	49.0 ± 7.6	Ni	11.0 ± 5.8	Ti	223 ± 9	Ba	399 ± 228
Element	Concentration (ppm)												
Cu	49.0 ± 7.6												
Ni	11.0 ± 5.8												
Ti	223 ± 9												
Ba	399 ± 228												
4		Red bottle	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Zn</td> <td>153 ± 11</td> </tr> <tr> <td>Ti</td> <td>43.3 ± 4.5</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Zn	153 ± 11	Ti	43.3 ± 4.5				
Element	Concentration (ppm)												
Zn	153 ± 11												
Ti	43.3 ± 4.5												

5a,b



Red top of
squeeze
bottle (a)

Element	Concentration (ppm)
Ba	402 ± 243

Grey
squeeze
bottle (b)

Element	Concentration (ppm)
Cr	19.4 ± 4.5

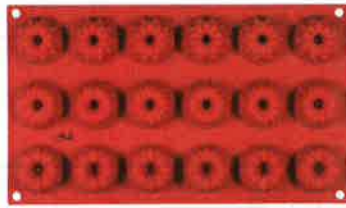
6



Black food
tray

Element	Concentration (ppm)
Zn	84.1 ± 9.6
Cr	34.1 ± 2.0
Ti	65.7 ± 2.9
Sb	276 ± 53
Br	6.75 ± 4.28

7



Red rubber
tray

Element	Concentration (ppm)
Ni	9.6 ± 6.2
Ti	55.4 ± 3.0

8



Red Lego
box

Element	Concentration (ppm)
Cu	11.7 ± 7.8
Ti	23.0 ± 4.1
Ba	483 ± 282

9



Red ice
cube tray

Element	Concentration (ppm)
Cr	24.8 ± 4.9

10a,b

Red pump
body (a)

Element	Concentration (ppm)
Ti	271 ± 8
Ba	1443 ± 240
Sn	43.3 ± 28.5

Red pump
black hose
(b)

Element	Concentration (ppm)
Cr	21.0 ± 3.1

11



Yellow bag

Element	Concentration (ppm)
Pb	2049 ± 141
Cr	333 ± 30
Ti	406 ± 50
Ba	2195 ± 759
Sb	245 ± 110
Cd	561 ± 76
Br	33.4 ± 14.3

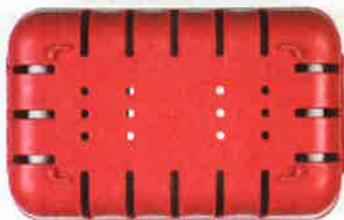
12



Red bag

Element	Concentration (ppm)
Pb	4379 ± 122
Zn	139 ± 26
Cr	1050 ± 37
Ti	1816 ± 81
Ba	1335 ± 274
Sb	5355 ± 128
Sn	95.7 ± 43.3

13

Red
drainer

Element	Concentration (ppm)
Ti	512 ± 20

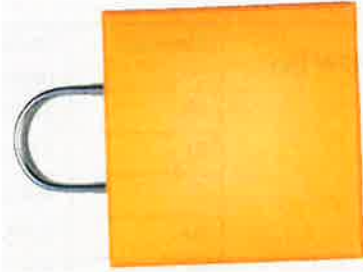
14



Red food box

Element	Concentration (ppm)
Zn	34.5 ± 6.0
Ti	24.7 ± 3.3

15



Yellow chopping board

16



Green bowl

Element	Concentration (ppm)
Ba	534 ± 266

17



Black kettle lid

Element	Concentration (ppm)
Zn	28.2 ± 6.4
Ti	284 ± 12
Ba	1094 ± 254
Br	19.7 ± 3.1

18



Red tooth brush

Element	Concentration (ppm)
Ti	46.1 ± 3.6

19



Yellow
lemon

Element	Concentration (ppm)
Ti	564 ± 10
Ba	451 ± 242

20



Green peg

Element	Concentration (ppm)
Pb	1465 ± 38
Zn	24.1 ± 5.1
Cr	145 ± 4
Ti	167 ± 7
Ba	529 ± 233
Sb	94 ± 34
Br	24.2 ± 4.2

21



Green tube
from water
can


Element	Concentration (ppm)
Zn	365 ± 16
Cu	16.7 ± 7.5
Ti	39.5 ± 4.9
Ba	442 ± 228

22



Green
crocodile


Element	Concentration (ppm)
Zn	98.1 ± 21.4
Ti	511 ± 131
Ba	2024 ± 365

23		Pink ruler	Element	Concentration (ppm)
			Pb	11.4 ± 4.4
			Zn	159 ± 10
			Ti	5876 ± 87
			Ba	353 ± 223

24		Grey hairbrush	Element	Concentration (ppm)
			Zn	86.8 ± 6.6
			Ti	215 ± 8

25		Blue bag	Element	Concentration (ppm)
			Zn	103 ± 47
			Ti	1738 ± 111
			Ba	963 ± 360
			Sn	101 ± 59
			Br	22.7 ± 11.6

26		Black Hoover end piece	Element	Concentration (ppm)
			Zn	18.9 ± 8.4
			Ti	1208 ± 36
			Cd	1238 ± 63

27		Red flag	Element	Concentration (ppm)
			Zn	64.7 ± 9.3
			Ni	11.2 ± 7.4
			Ti	5005 ± 250

28

Red
dinosaur

Element	Concentration (ppm)
Zn	284 ± 31
Ti	67 ± 10

29

White
football

Element	Concentration (ppm)
Zn	557 ± 57
Ti	33801 ± 723
Ba	243 ± 121
Sb	35.0 ± 19.7

30



White ruler

Element	Concentration (ppm)
Pb	18.8 ± 8.1
Zn	187 ± 20
Ti	30588 ± 510
Sb	83.2 ± 47.0

31

Red doll
shape

Element	Concentration (ppm)
Zn	258 ± 18
Cu	18.0 ± 10.9
Cr	26.4 ± 5.7
Ti	36.3 ± 6.3

32

Blue hand
shape

Element	Concentration (ppm)
Cu	56.4 ± 10.5
Cr	19.4 ± 5.1
Ti	672 ± 22

33

Red foot
shape

Element	Concentration (ppm)
Cu	19.8 ± 10.7
Cr	35.7 ± 6.2
Ti	226 ± 12.6
Ba	727 ± 285
Sn	65 ± 35

34



Yellow rake

Element	Concentration (ppm)
Ti	445 ± 15
Ba	374 ± 237

35

Yellow
sand toy

Element	Concentration (ppm)
Ti	1145 ± 29
Ba	554 ± 300

36a,b

Head &
Shoulders
shampoo
bottle (a)

Element	Concentration (ppm)
Zn	986 ± 37
Cu	50.0 ± 14.1
Cr	42.2 ± 6.2
Ti	9.54 ± 5.53

Head &
Shoulders
blue cap
(b)

Element	Concentration (ppm)
Cu	41.1 ± 10.2
Cr	20.0 ± 4.0
Ti	9.15 ± 3.41

37a,b,c,d



Red balloon (a)

Element	Concentration (ppm)
Zn	1366 ± 52
Ti	4716 ± 113
Ba	880 ± 400

Dark blue balloon (b)

Element	Concentration (ppm)
Zn	1884 ± 73
Cu	1127 ± 53
Ti	9198 ± 216
Ba	811 ± 460

Green balloon (c)

Element	Concentration (ppm)
Zn	1504 ± 58
Cu	200 ± 22
Ti	9664 ± 217

Yellow balloon (d)

Element	Concentration (ppm)
Zn	1323 ± 64
Ti	7408 ± 212

38



Tree shape stick

Element	Concentration (ppm)
Zn	118 ± 11
Cu	12.7 ± 7.8
Ti	762 ± 23

39



Blue brush handle

Element	Concentration (ppm)
Ti	6.71 ± 1.82
Ba	348 ± 214

40



Blue spoon

Element	Concentration (ppm)
Zn	86.8 ± 11.4
Cr	28.6 ± 4.7
Ba	705 ± 313

41a		Grey box	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Ti</td> <td>779 ± 17</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Ti	779 ± 17				
Element	Concentration (ppm)										
Ti	779 ± 17										
41b		Grey box cover	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Ti</td> <td>383 ± 12</td> </tr> <tr> <td>Ba</td> <td>592 ± 302</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Ti	383 ± 12	Ba	592 ± 302		
Element	Concentration (ppm)										
Ti	383 ± 12										
Ba	592 ± 302										
42		Green garden bag	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Zn</td> <td>267 ± 45</td> </tr> <tr> <td>Cu</td> <td>110 ± 48</td> </tr> <tr> <td>Ti</td> <td>29559 ± 1576</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Zn	267 ± 45	Cu	110 ± 48	Ti	29559 ± 1576
Element	Concentration (ppm)										
Zn	267 ± 45										
Cu	110 ± 48										
Ti	29559 ± 1576										
43		White bag	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Zn</td> <td>274 ± 69</td> </tr> <tr> <td>Ti</td> <td>35808 ± 1603</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Zn	274 ± 69	Ti	35808 ± 1603		
Element	Concentration (ppm)										
Zn	274 ± 69										
Ti	35808 ± 1603										
44a,b,c		Yellow fork (a)	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Ti</td> <td>758 ± 21</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Ti	758 ± 21				
Element	Concentration (ppm)										
Ti	758 ± 21										
		Orange fork (b)	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Ti</td> <td>568 ± 17</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Ti	568 ± 17				
Element	Concentration (ppm)										
Ti	568 ± 17										
		Blue fork (c)	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Ti</td> <td>831 ± 24</td> </tr> <tr> <td>Ba</td> <td>628 ± 304</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Ti	831 ± 24	Ba	628 ± 304		
Element	Concentration (ppm)										
Ti	831 ± 24										
Ba	628 ± 304										

45a,b,c,d



Yellow spoon (a)

Element	Concentration (ppm)
Zn	43.6 ± 7.8
Ni	17.9 ± 7.3
Ti	1402 ± 35
Ba	4730 ± 297
Sb	172 ± 42

Orange spoon (b)

Element	Concentration (ppm)
Zn	65.1 ± 8.2
Ti	723 ± 22
Ba	3538 ± 275

Pink spoon (c)

Element	Concentration (ppm)
Zn	47.5 ± 8.0
Ti	1566 ± 35
Ba	1291 ± 293

Green spoon (d)

Element	Concentration (ppm)
Zn	79.5 ± 8.7
Cu	50.6 ± 8.2
Ti	667 ± 17
Ba	510 ± 256

46



Coat hanger


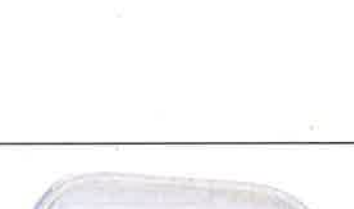


Element	Concentration (ppm)
Zn	150 ± 14
Cu	16.3 ± 9.6
Ti	8687 ± 152
Br	8.08 ± 3.23

47



Flags

Element	Concentration (ppm)
Zn	3139 ± 212
Cr	50.9 ± 12.8
Ti	18268 ± 801

48a,b		Cindy phone light pink (a)	Element	Concentration (ppm)
			Zn	78.6 ± 7.0
			Ti	4.57 ± 2.34
		Cindy phone dark pink (b)	Element	Concentration (ppm)
			Zn	58.2 ± 8.3
			Ti	306 ± 12
49		White zipped purse	Element	Concentration (ppm)
			Zn	71.1 ± 32.2
			Ti	38315 ± 1161
			Ba	1051 ± 538
50		Green pen	Element	Concentration (ppm)
			Cu	11.8 ± 3.2
			Ti	3159 ± 31

3.2 Results classified by chemical elements

Concentration values are shown for all objects that contain a given element, in decreasing order. Two elements have not been found in any object: arsenic and mercury. Values for two elements whose presence is widespread in plastics, but that are not included in the contract, are shown in graphical form at the end of the section (barium and titanium). The total number of analysis is 63.

Antimony

Sample #	Sample description	Concentration (ppm)
12	Red bag	5355 ± 128
6	Black food tray	276 ± 53
11	Yellow bag	245 ± 110
45a	Yellow spoon	172 ± 42
20	Green peg	94 ± 34
30	White ruler	83.2 ± 47.0
29	White football PVC	35.0 ± 19.7

See Section 4 for meaning of orange shading.

Bromine

Sample #	Sample description	Concentration (ppm)
11	Yellow bag	33.4 ± 14.3
20	Green peg	24.2 ± 4.2
25	Blue bag	22.7 ± 11.6
46	Coat hanger	8.08 ± 3.23
6	Black food tray	6.75 ± 4.28

See Section 4 for meaning of orange shading.

Cadmium

Sample #	Sample description	Concentration (ppm)
26	Black Hoover end piece	1238 ± 63
11	Yellow bag	561 ± 76

Chromium

Sample #	Sample description	Concentration (ppm)
12	Red bag	1050 ± 37
11	Yellow bag	333 ± 30
20	Green peg	145 ± 4
47	Flags	50.9 ± 12.8
36a	Head & Shoulders bottle	42.2 ± 6.2
33	Red foot shape	35.7 ± 6.2
6	Black food tray	34.1 ± 2.0
40	Blue spoon	28.7 ± 4.7
31	Red doll shape	26.4 ± 5.7
9	Red ice cube tray	24.8 ± 4.9
10b	Red pump black hose	21.0 ± 3.1
36b	Head & Shoulders blue cap	20.0 ± 4.0
5b	Grey squeeze bottle	19.4 ± 4.5
32	Blue hand shape	19.4 ± 5.1

See Section 4 for meaning of orange shading.

Copper

Sample #	Sample description	Concentration (ppm)
37b	Dark blue balloon	1127 ± 53
37c	Green balloon	200 ± 22
42	Green garden bag	110 ± 48
32	Blue hand shape	56.4 ± 10.5
45d	Green spoon	50.6 ± 8.2
36a	Head & Shoulders bottle	50.0 ± 14.1
3	Blue bottle	49.0 ± 7.6
2	Green shoe	48.8 ± 28.1
36b	Head & Shoulders blue cap	41.1 ± 10.2
33	Red foot shape	19.8 ± 10.7
31	Red doll shape	18.0 ± 10.9
21	Green tube from water can	16.7 ± 7.5
46	Coat hanger	16.3 ± 9.6
38	Tree shape stick	12.7 ± 7.8
50	Green pen	11.8 ± 3.2
8	Red Lego box	11.7 ± 7.8

Lead

Sample #	Sample description	Concentration (ppm)
12	Red bag	4379 ± 122
11	Yellow bag	2049 ± 141
20	Green peg	1465 ± 38
30	White ruler	18.8 ± 8.1
23	Pink ruler	11.4 ± 4.4

See Section 4 for meaning of orange shading.

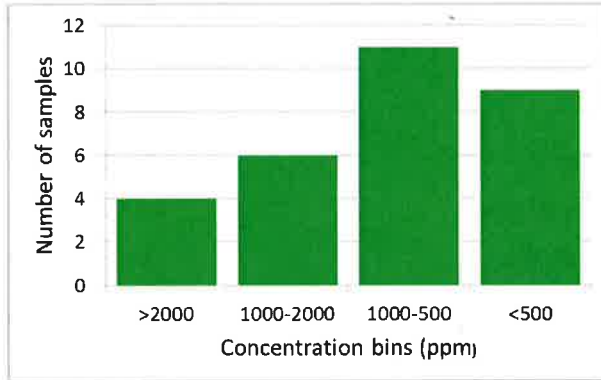
Nickel

Sample #	Sample description	Concentration (ppm)
45a	Yellow spoon	17.9 ± 7.3
27	Red flag	11.2 ± 7.4
3	Blue bottle	11.0 ± 5.8
7	Red rubber tray	9.6 ± 6.2

Zinc

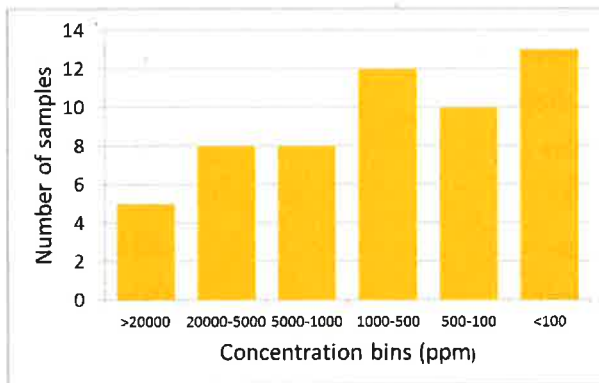
Sample #	Sample description	Concentration (ppm)
2	Green shoe	5584 ± 148
47	Flags	3139 ± 212
37a	Red balloon	1366 ± 52
37b	Dark blue balloon	1884 ± 73
37c	Green balloon	1504 ± 58
37d	Yellow balloon	1323 ± 64
36	Head and shoulders shampoo	986 ± 37
29	White football	557 ± 57
21	Green tube from water can	365 ± 16
28	Red dinosaur	284 ± 31
43	White bag	274 ± 69
42	Green garden bag	267 ± 45
31	Red doll shape	258 ± 18
30	White ruler	187 ± 20
23	Pink ruler	159 ± 10
4	Red bottle	153 ± 11
46	Coat hanger	150 ± 14
12	Red bag	139 ± 26
38	Tree shape stick	118 ± 11
25	Blue bag	103 ± 47
22	Green crocodile	98.1 ± 21.4
24	Grey hairbrush	86.8 ± 6.6
6	Black food tray	84.1 ± 9.6
45d	Green spoon	79.5 ± 8.7
48a	Cindy phone light pink	78.6 ± 7.0
49	White zipped purse	71.1 ± 32.2
45b	Orange spoon	65.1 ± 8.2
27	Red flag	64.7 ± 9.3
48b	Cndy phone dark pink	58.2 ± 8.3
45a	Yellow spoon	43.6 ± 7.8
45c	Pink spoon	47.5 ± 8.0
14	Red food box	34.5 ± 6.0
17	Black kettle lid	28.2 ± 6.4
20	Green peg	24.1 ± 5.1
26	Black hoover end piece	18.9 ± 8.4

Barium (all concentrations in ppm)



Count	30
Min	243
1 Q	459
Median	666
3 Q	1242
Max	4730
Mean	1038
SD	987

Titanium (all concentrations in ppm)



Count	56
Min	4.57
1 Q	203
Median	618
3 Q	3549
Max	38315
Mean	4944
SD	9877

3.3 Results of FREITAG bags

The nine FREITAG bags sent by the ASED in November 2018 were analysed (total number of analysis: 17 since some of the bags showed more than one colour). The samples are numbered A to I.

A



Element	Concentration (ppm)
Pb	3452 ± 250
Zn	171 ± 85
Cr	795 ± 77
Ba	12713 ± 882
Sb	6106 ± 330
Sn	124 ± 69

B



Blue

Element	Concentration (ppm)
Pb	1322 ± 132
Zn	139 ± 78
Cr	181 ± 41
Cu	797 ± 142
Ti	2176 ± 201
Ba	1574 ± 465
Sb	5545 ± 299

Yellow

Element	Concentration (ppm)
Pb	900 ± 86
Zn	142 ± 53
Cr	51.7 ± 20.0
Cu	455 ± 88
Ti	19706 ± 736
Ba	707 ± 447
Sb	2152 ± 147

C



Blue

Element	Concentration (ppm)
Zn	163 ± 67
Cu	131 ± 78
Ti	11189 ± 563
Ba	1198 ± 466
Sb	8136 ± 384
Sn	132 ± 65

Yellow

Element	Concentration (ppm)
Zn	287 ± 73
Ti	10427 ± 527
Ba	1193 ± 575
Sb	2763 ± 198

D



White

Element	Concentration (ppm)
Zn	166 ± 78
Ti	11981 ± 660
Ba	1314 ± 500
Sb	8362 ± 432
Sn	166 ± 72

Blue

Element	Concentration (ppm)
Zn	150 ± 66
Ti	29377 ± 3314
Ba	1551 ± 615
Sb	9686 ± 489

E



Element	Concentration (ppm)
Zn	243 ± 71
Ba	620 ± 380
Sb	3410 ± 196

F



Orange

Element	Concentration (ppm)
Pb	2367 ± 144
Zn	108 ± 46
Cr	700 ± 49
Ti	130 ± 60
Ba	768 ± 361
Sb	1452 ± 114

White

Element	Concentration (ppm)
Pb	3806 ± 273
Zn	166 ± 72
Ti	114332 ± 4507
Sb	6186 ± 316
Br	40.8 ± 23.6

G




Element	Concentration (ppm)
Zn	104 ± 49
Ti	1425 ± 240
Sb	6455 ± 287
Sn	106 ± 55

H



Purple

Element	Concentration (ppm)
Zn	181 ± 74
Ti	11717 ± 820
Ba	7350 ± 840
Sb	9974 ± 526
As	55.6 ± 32.4

	White	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Zn</td> <td>91.8 ± 48.7</td> </tr> <tr> <td>Ti</td> <td>9741 ± 1364</td> </tr> <tr> <td>Ba</td> <td>817 ± 384</td> </tr> <tr> <td>Sb</td> <td>4011 ± 204</td> </tr> <tr> <td>As</td> <td>35.6 ± 19.4</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Zn	91.8 ± 48.7	Ti	9741 ± 1364	Ba	817 ± 384	Sb	4011 ± 204	As	35.6 ± 19.4				
Element	Concentration (ppm)																	
Zn	91.8 ± 48.7																	
Ti	9741 ± 1364																	
Ba	817 ± 384																	
Sb	4011 ± 204																	
As	35.6 ± 19.4																	
	Red	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Pb</td> <td>50.1 ± 23.1</td> </tr> <tr> <td>Zn</td> <td>178 ± 62</td> </tr> <tr> <td>Ba</td> <td>1043 ± 422</td> </tr> <tr> <td>Sb</td> <td>1855 ± 139</td> </tr> <tr> <td>Br</td> <td>18.4 ± 11.0</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Pb	50.1 ± 23.1	Zn	178 ± 62	Ba	1043 ± 422	Sb	1855 ± 139	Br	18.4 ± 11.0				
	Element	Concentration (ppm)																
Pb	50.1 ± 23.1																	
Zn	178 ± 62																	
Ba	1043 ± 422																	
Sb	1855 ± 139																	
Br	18.4 ± 11.0																	
	Silver	<table border="1"> <thead> <tr> <th>Element</th> <th>Concentration (ppm)</th> </tr> </thead> <tbody> <tr> <td>Pb</td> <td>92.3 ± 27.0</td> </tr> <tr> <td>Zn</td> <td>127 ± 45</td> </tr> <tr> <td>Ti</td> <td>167 ± 55</td> </tr> <tr> <td>Ba</td> <td>1102 ± 505</td> </tr> <tr> <td>Sb</td> <td>5922 ± 274</td> </tr> <tr> <td>Sn</td> <td>101 ± 67</td> </tr> <tr> <td>Br</td> <td>155 ± 20</td> </tr> </tbody> </table>	Element	Concentration (ppm)	Pb	92.3 ± 27.0	Zn	127 ± 45	Ti	167 ± 55	Ba	1102 ± 505	Sb	5922 ± 274	Sn	101 ± 67	Br	155 ± 20
Element	Concentration (ppm)																	
Pb	92.3 ± 27.0																	
Zn	127 ± 45																	
Ti	167 ± 55																	
Ba	1102 ± 505																	
Sb	5922 ± 274																	
Sn	101 ± 67																	
Br	155 ± 20																	

4. Discussion

4.1 The initial 50 objects

Although the number of objects analysed is too low to be able to draw general conclusions about the presence of potential toxic elements in Swiss plastic consumer products, some aspects deserve to be mentioned:

- Most of the samples analysed do not contain hazardous elements.
- A limited number of objects appear to be of clear concern: 11 (yellow bag), 12 (red bag), 20 (green peg) and 26 (black hoover end piece).
- All samples (except one, 15, yellow chopping board) contain one or more of the chemical elements analysed. In particular, the presence of titanium, zinc and barium is widespread. Even if the extensive presence of these chemical elements

in plastics might be of no immediate toxicological concern, it has clear implications when considering their possible recycling.

- Two noxious elements are entirely absent in these samples: arsenic and mercury.
- The simultaneous presence of antimony and bromine in some objects (highlighted in orange in the respective tables), where no need for the presence of flame retardants is clear, points to plastic illegally recycled from WEEE (Waste electronic and electric equipment). The case is well documented in the case of black one-use trays like sample 6 (A. Turner and M. Filella, Bromine in plastic consumer products – Evidence for the widespread recycling of electronic waste. *Sci. Total Env.* 601–602 (2017) 374–379).
- The high concentration of lead in three objects: 12 (red bag), 11 (yellow bag) and 20 (green peg) needs to be mentioned, particularly because they are not legacy objects but products available now in the market. Since these three samples also contain the highest chromium concentrations, it can be speculated that they contain lead chromate (i.e., Cr(VI)) as a pigment, alone or in combination with other substances.
- The presence of some chemical elements in manufactured products is regulated by the *Chemical Risk Reduction Ordinance related to the Use for Certain Particularly Dangerous Substances* (OCRR), “which manufacturers and traders are required to comply with regarding the manufacture and placing in the market of certain substances, preparations and articles”. The chemical elements mentioned are arsenic, cadmium, chromium, organostannic compounds, lead, mercury and some brominated compounds. The presence of a given element and the concentration allowed depends on the use of the manufactured product. There are other more restrictive regulations concerning particular objects such as toys (817.023.11; *Ordonnance sur les jouets*, OSJo; *Spielzeugverordnung*, VSS; *Ordinanza sui giocattoli*, OSG) or the objects in contact with food (817.023.21; *Ordonnance du DFI sur les matériaux et objets destinés à entrer en contact avec les denrées alimentaires*; *Verordnung des EDI über Materialien und Gegenstände, die dazu bestimmt sind, mit Lebensmitteln in Berührung zu kommen*; *Ordinanza del DFI sui materiali e gli oggetti destinati a entrare in contatto con le derrate alimentari*) that might apply to some of the objects considered here.

4.2 The FREITAG bags

The trace element contents of nine FREITAG bags was measured. According to the firm webpage, these bags are produced from used truck tarp. The results obtained show that a third of the analysed bags (3) contained high amounts of lead, one of them small concentrations of arsenic and another one of lead. They all have high concentrations of antimony.

4.3 General considerations

According to the results obtained in this study, the following recommendations are made:

- The analysis of other plastic consumer products available in Switzerland, with a focus on the categories more prone to contain problematic elements.
- The preparation of a summary of the regulated values in Switzerland and in the European Union for different uses (e.g., toys, plastic in contact with food, etc.).

ANNEX 1. List of products and pictures sent by ASED.

ASED - UNIGE: Liste des objets plastiques à analyser

N°	Description	Lieu d'achat/Provenance / Année
1	Flip-flop noir	?
2	Imitation crocs vert	Landi/made in China/ 2018
3	Gourde bleue	made in CH/ 2015
4	Gourde Camelbag rouge	made in China/ 2014
5	Gourde grise	made in CH/ 2015
6	Barquette alimentaire noire	Migros/made in ?/2017
7	Forme cupcake rouge silicone	Migros/made in Italy/2018
8	Lego lunchbox	Migros/made in Poland/ 2018
9	Forme pour faire glaçons rouge	Migros/made in CH/ 2018
10	Pompe à air rouge	?
11	LikeaBag jaune	made in India/2007
12	Likeabag rouge	made in EU/2017
13	Corbeille rouge foncée pour égoutter fruits	Migros/made in China/2018
14	Box alimentaire rouge	Migros/made in New Zealand/ 2018
15	Planche à découper, jaune	?/2008
16	Bol alimentaire vert	Migros/made in China/2015
17	Couvercle bouilloire noir	Landi/made in China/2018
18	Brosse à dent enfant rouge	Migros/made in CH/ 2018
19	Flacon jus de citron jaune à couvercle vert	Coop/made in ?/2018
20	Pince à linge verte	Landi/made in ?/ 2016
21	Arrosoir vert	?/ 2008
22	Crocodile gonflable vert	Made in China/ /2011
23	Règle TRIDEL rouge foncée	?/2014
24	Brosse à cheveux noire	Migros/?/2008
25	Sacchoche Musto	Made in China/ 2015
26	Embout aspirateur noir	Miele/?/2002
27	Drapeaux suisses	Migros/made in China/2018
28	Jouet dragon rouge	Tiger of Copenhagen/made in China/2018
29	Ballon foot	?/2018
30	Kutch Faber Castell	Made in Germany/1998
31	Forme jouet sable rouge (fille)	made in Germany/2018

PAQUET NO. 7

ASED - UNIGE: Liste des objets plastiques à analyser

N°	Description	Lieu d'achat/Provenance / Année
32	Forme jouet sable bleue (main)	made in China/2018
33	Forme jouet sable rouge (pied)	made in China/2018
34	Râteau sable jaune	made in Denmark/2018
35	Forme jouet sable jaune (phare)	made in Germany/2018
36	Flacon shampoing, 25% mat. Recycée	?/2018
37	Ballons gonfables multicolores	made in Italy/2018
38	Cocktail-stick vert	made in China/2018
39	Balayette bleue	?/1995
40	Cuillère pour glace, bleue	?/2018
41	Box rangement grise (plastique recyclé)	Migros/made in CH/ 2018
42	Sac plastique Migros (recycling)	Migros/ 2018
43	Sac plastique Coop (recycling)	Coop/2018
44	Fourchettes one way multicolore	Migros/made in CH/ 2018
45	Cuillères one way multicolore	Migros/made in CH/ 2018
46	Cintre noir	?
47	Drapeaux suisses divers	?/1998
48	Jouet natel rose-rouge	2013
49	Sacchoche pour cosmétiques blanche/verte	made in China/2018
50	Stabilo vert	made in ?/2017

PAGE 2

...









24

28

23

22

27

26

27

25

21

MUSTO
PERFORMANCE



