Electronic Supplementary Information (ESI)

Contents

Note: In Tables 1 – 6 the significant number of digits are given according to GUM and EURACHEM guidelines, where the uncertainty determines the significant number of digits to be presented with the value.

ESI Table 1: Measured values of certified (*) and non-certified elements of ERM®-EZ505: Analytical method used for investigation (TQ: Totalquant Method); *LOQ* and measurement result (average of n = 33); combined uncertainties (u_c, k = 1); relative contribution of measurement precision (u_{meas}) and replicate analysis (u_{rep}) to u_c.

Element	Method	*LOQ* / µg g^{-1}	Mass fraction (measured data) (n = 33)	Combined uncertainty u_c	*Relative contribution* u_{meas} / %	*Relative contribution* u_{rep} / %
Al	ICP-OES	685	30.4 mg g^{-1}	1.6 mg g^{-1}	13	87
Ag*	ICP-OES	11	0.52 mg g^{-1}	0.16 mg g^{-1}	1	99
As	ICP-MS	0.63	266 µg g^{-1}	18 µg g^{-1}	56	44
Au*	ICP-MS	0.024	265 µg g^{-1}	15 µg g^{-1}	16	84
Ba	ICP-OES	9.7	2.40 mg g^{-1}	0.09 mg g^{-1}	76	24
Be*	ICP-OES	0.054	69.6 µg g^{-1}	3.1 µg g^{-1}	39	61
Bi	ICP-MS	0.010	85 µg g^{-1}	5 µg g^{-1}	13	87
Ca	ICP-OES	1936	18.9 mg g^{-1}	0.7 mg g^{-1}	5	95
Cd	ICP-MS	0.10	8.5 µg g^{-1}	1.4 µg g^{-1}	42	58
Co	ICP-MS	0.0094	255 µg g^{-1}	10 µg g^{-1}	30	70
Cr	ICP-OES	2.7	1.34 mg g^{-1}	0.10 mg g^{-1}	1	99
Cu*	ICP-OES	24	167 mg g^{-1}	5 mg g^{-1}	7	93
Fe	ICP-OES	55	316 mg g^{-1}	10 mg g^{-1}	11	89
Ga	ICP-MS	0.36	16.8 µg g^{-1}	2.9 µg g^{-1}	43	57
Ge	ICP-MS	0.26	3.7 µg g^{-1}	1.0 µg g^{-1}	65	35
Hf	ICP-MS	0.012	6.4 µg g^{-1}	3.2 µg g^{-1}	1	99
Hg	ICP-MS	0.078	0.4 µg g^{-1}	0.3 µg g^{-1}	80	20
In*	ICP-MS	0.010	101 µg g^{-1}	5 µg g^{-1}	35	65
Li	ICP-OES	0.54	13.0 µg g^{-1}	0.7 µg g^{-1}	<1	100
Mg	ICP-OES	49	1.66 mg g^{-1}	0.04 mg g^{-1}	19	81
Mn	ICP-OES	0.60	3.95 mg g^{-1}	0.20 mg g^{-1}	1	99
Mo	ICP-MS	0.054	242 µg g^{-1}	27 µg g^{-1}	4	96
Na	ICP-OES	318	11.4 mg g^{-1}	0.4 mg g^{-1}	60	40
Ni*	ICP-OES	16	4.73 mg g^{-1}	0.18 mg g^{-1}	70	30
Nb	ICP-MS (TQ)	0.00049	35 µg g^{-1}	6 µg g^{-1}	65	35
Pb	ICP-MS	0.47	7.1 mg g^{-1}	0.3 mg g^{-1}	22	78
Pd*	ICP-OES	0.89	91 µg g^{-1}	11 µg g^{-1}	12	88
Pt*	ICP-OES	1.7	10.2 µg g^{-1}	3.5 µg g^{-1}	2	98
Rb	ICP-MS	0.030	5.7 µg g^{-1}	2.1 µg g^{-1}	17	83
Sb	ICP-MS	0.021	2.56 mg g^{-1}	0.13 mg g^{-1}	20	80
Si	ICP-OES	78	51.7 mg g^{-1}	1.7 mg g^{-1}	19	80
Sn	ICP-MS	0.13	9.9 mg g^{-1}	0.4 mg g^{-1}	25	76
Sr	ICP-OES	14	322 µg g^{-1}	10 µg g^{-1}	6	94
Ta	ICP-OES	4.1	0.79 mg g^{-1}	0.10 mg g^{-1}	2	98
Te	ICP-MS	0.0035	4 µg g^{-1}	6 µg g^{-1}	63	37
Ti	ICP-OES	20	2.05 mg g^{-1}	0.14 mg g^{-1}	31	69
Tl	ICP-MS	0.0024	11 µg g^{-1}	7 µg g^{-1}	<1	100
V	ICP-MS	0.017	31.5 µg g^{-1}	1.8 µg g^{-1}	58	42
W	ICP-OES	23	0.59 mg g^{-1}	0.10 mg g^{-1}	3	97
Zn	ICP-OES	22	17.9 mg g^{-1}	0.5 mg g^{-1}	17	83
Zr	ICP-MS	0.55	0.31 mg g^{-1}	0.08 mg g^{-1}	2	98

Table 1 continued (REE)

Element	ICP-Method	*LOQ* / ng g^{-1}	Mass fraction (measured data) (*n* = 33)	Combined uncertainty u_c	*Relative contribution* u_{meas} / %	*Relative contribution* u_{rep} / %
Ce	ICP-MS (TQ)	83	36 µg g^{-1}	5 µg g^{-1}	44	56
Dy	ICP-MS (TQ)	40	2.2 µg g^{-1}	1.2 µg g^{-1}	4	96
Er	ICP-MS (TQ)	0.06	1.26 µg g^{-1}	0.15 µg g^{-1}	69	31
Eu	ICP-MS (TQ)	0.06	0.48 µg g^{-1}	0.05 µg g^{-1}	80	20
Gd	ICP-MS (TQ)	2.6	2.0 µg g^{-1}	0.7 µg g^{-1}	8	92
Ho	ICP-MS (TQ)	0.02	0.58 µg g^{-1}	0.21 µg g^{-1}	7	93
La	ICP-MS (TQ)	4.1	36 µg g^{-1}	5 µg g^{-1}	53	47
Lu	ICP-MS (TQ)	0.04	74 ng g^{-1}	14 ng g^{-1}	28	72
Nd	ICP-MS (TQ)	243	106 µg g^{-1}	36 µg g^{-1}	9	91
Pr	ICP-MS (TQ)	71	7.1 µg g^{-1}	3.2 µg g^{-1}	5	95
Sc	ICP-MS (TQ)	61	7.4 µg g^{-1}	3.1 µg g^{-1}	6	94
Sm	ICP-MS (TQ)	0.55	11.4 µg g^{-1}	1.3 µg g^{-1}	7	23
Tb	ICP-MS (TQ)	1.0	0.27 µg g^{-1}	0.07 µg g^{-1}	13	87
Tm	ICP-MS (TQ)	0.02	74 ng g^{-1}	10 ng g^{-1}	58	42
Y	ICP-MS (TQ)	3.3	6.6 µg g^{-1}	1.4 µg g^{-1}	21	80
Yb	ICP-MS (TQ)	0.19	0.50 µg g-1	0.06 µg g^{-1}	64	36

ESI Table 2: Mass fractions of elements in printed circuit boards (PCB) from smartphones (n = 3) from three different manufacturers in µg g^{-1} from averaged triplicates of each phone. 'Min' corresponds to the lowest value from three smartphones. 'Max' corresponds to the highest value from three smartphones. Data is sorted by decreasing average mass fraction (see also Figure 1).

Element	Mass fraction min	Mass fraction average (n = 3)	Mass fraction max
Cu	306 mg g^{-1}	391 mg g^{-1}	495 mg g^{-1}
Fe	19 mg g^{-1}	142 mg g^{-1}	251 mg g^{-1}
Si	45 mg g^{-1}	62 mg g^{-1}	80 mg g^{-1}
Ni	42 mg g^{-1}	60 mg g^{-1}	83 mg g^{-1}
Sn	31 mg g^{-1}	37 mg g^{-1}	42 mg g^{-1}
Zn	3.8 mg g^{-1}	26 mg g^{-1}	69 mg g^{-1}
Ba	18 mg g^{-1}	19 mg g^{-1}	20 mg g^{-1}
Al	11 mg g^{-1}	18 mg g^{-1}	25 mg g^{-1}
Cr	0.12 mg g^{-1}	14.16 mg g^{-1}	41.70 mg g^{-1}
Ca	8.3 mg g^{-1}	10.0 mg g^{-1}	12.3 mg g^{-1}
Ti	6.5 mg g^{-1}	7.0 mg g^{-1}	7.3 mg g^{-1}
Mn	478 µg g^{-1}	2608 µg g^{-1}	4940 µg g^{-1}
Ta	2023 µg g^{-1}	2385 µg g^{-1}	2804 µg g^{-1}
Mg	701 µg g^{-1}	1458 µg g^{-1}	2000 µg g^{-1}
W	855 µg g^{-1}	1236 µg g^{-1}	1744 µg g^{-1}
Au	551 µg g^{-1}	1081 µg g^{-1}	1410 µg g^{-1}
Zr	692 µg g^{-1}	960 µg g^{-1}	1280 µg g^{-1}
REE	485 µg g^{-1}	727 µg g^{-1}	1148 µg g^{-1}
Pb	283 µg g^{-1}	496 µg g^{-1}	607 µg g^{-1}
Co	274 µg g^{-1}	439 µg g^{-1}	543 µg g^{-1}
Na	391 µg g^{-1}	402 µg g^{-1}	412 µg g^{-1}
Ag	308 µg g^{-1}	367 µg g^{-1}	428 µg g^{-1}
Sr	232 µg g^{-1}	296 µg g^{-1}	372 µg g^{-1}
Mo	75 µg g^{-1}	195 µg g^{-1}	265 µg g^{-1}
Ga	103 µg g^{-1}	183 µg g^{-1}	267 µg g^{-1}
As	111 µg g^{-1}	172 µg g^{-1}	258 µg g^{-1}
In	134 µg g^{-1}	140 µg g^{-1}	144 µg g^{-1}
Pd	99 µg g^{-1}	126 µg g^{-1}	178 µg g^{-1}
V	13 µg g^{-1}	113 µg g^{-1}	187 µg g^{-1}
Li	35 µg g^{-1}	38 µg g^{-1}	40 µg g^{-1}
Bi	16 µg g^{-1}	36 µg g^{-1}	54 µg g^{-1}
Nb	10 µg g^{-1}	28 µg g^{-1}	44 µg g^{-1}
Hf	18 µg g^{-1}	23 µg g^{-1}	28 µg g^{-1}
Pt	5 µg g^{-1}	13 µg g^{-1}	25 µg g^{-1}
Ge	4 µg g^{-1}	12 µg g^{-1}	20 µg g^{-1}
Sb	3 µg g^{-1}	8 µg g^{-1}	12 µg g^{-1}
Cd	0.6 µg g^{-1}	1.1 µg g^{-1}	1.7 µg g^{-1}
Be	< LOQ µg g^{-1}	0.6 µg g^{-1}	1.8 µg g^{-1}
Te	< LOQ µg g^{-1}	0.5 µg g^{-1}	1.5 µg g^{-1}

Table 2 continued

Rb	0.01 µg g^{-1}	0.48 µg g^{-1}	0.77 µg g^{-1}
Tl	< LOQ µg g^{-1}	0.33 µg g^{-1}	0.82 µg g^{-1}
Hg	< LOQ µg g^{-1}	0.15 µg g^{-1}	0.34 µg g^{-1}

ESI Table 3: Range of total amount of each element measured in PCB from different smartphone manufacturers (*n* = 3) from averaged triplicates. 'Min' corresponds to the lowest determined total amount in PCB from three smartphones. 'Max' corresponds to the highest determined total amount in PCB from three smartphones. Data is sorted by mass fraction of element in PCB, see ESI Table 2 (see also Figure 2). Values are given in three significant numbers of digits (with maximum 5 significant numbers of digits after the decimal point for values < 1 mg).

Element	Amount min / g	Amount average (*n* = 3) / g	Amount max / g
Cu	3.76	6.50	11.2
Fe	0.429	1.81	3.08
Si	0.730	0.915	1.03
Ni	0.504	1.03	1.89
Sn	0.385	0.599	0.949
Zn	0.0458	0.562	1.57
Ba	0.219	0.304	0.461
Al	0.130	0.277	0.394
Cr	0.0015	0.176	0.512
Ca	0.115	0.152	0.190
Ti	0.0784	0.110	0.166
Mn	0.0108	0.0336	0.0606
Ta	0.0248	0.0373	0.0530
Mg	0.00852	0.0248	0.0454
W	0.0105	0.0212	0.0397
Au	0.0125	0.0151	0.0173
Zr	0.00841	0.0162	0.0291
REE	0.00664	0.0114	0.0141
Pb	0.00344	0.00816	0.0136
Co	0.00609	0.00633	0.00666
Na	0.00496	0.00628	0.00889
Ag	0.00378	0.00576	0.00830
Sr	0.00285	0.00492	0.00847
Mo	0.00171	0.00264	0.00326
Ga	0.00219	0.00260	0.00327
As	0.00176	0.00249	0.00317
In	0.00165	0.00221	0.00327
Pd	0.00120	0.00189	0.00228
V	0.00029	0.00143	0.00229
Li	0.00043	0.00059	0.00084
Bi	0.00035	0.00049	0.00065
Nb	0.00022	0.00038	0.00054
Hf	0.00022	0.00038	0.00064
Pt	0.00009	0.00017	0.00031
Ge	0.00009	0.00016	0.00025
Sb	0.00007	0.00011	0.00015
Cd	0.00001	0.00002	0.00002
Be	< *LOQ*	0.00001	0.00002
Te	< *LOQ*	0.00001	0.00003

Table 3 continued

Rb	< 0.00001	0.00001	0.00002
Tl	< *LOQ*	0.00001	0.00001
Hg	< *LOQ*	< 0.00001	< 0.00001

ESI Table 4: Mass fractions of measured elements in entire PCB from different smartphone manufacturer (n = 3) in µg g^{-1} (see also Figure 1). Entire PCB comprises triplicate from PCB of each smartphone plus separately measured metal covers and contacts which were mounted on PCB. Uncertainties (u_c) correspond to total combined uncertainties with a coverage factor of k = 1. In the last rows, the number of elements > LOQ and the Loss on Ignition (w/w) are given.

	Smartphone I		Smartphone II		Smartphone III	
Element	Mass fraction (n = 3)	u_c	Mass fraction (n = 3)	u_c	Mass fraction (n = 3)	u_c
Ag	0.43 mg g^{-1}	0.15 mg g^{-1}	0.37 mg g^{-1}	0.09 mg g^{-1}	0.31 mg g^{-1}	0.07 mg g^{-1}
Al	25.2 mg g^{-1}	0.7 mg g^{-1}	17.3 mg g^{-1}	0.5 mg g^{-1}	10.6 mg g^{-1}	2.8 mg g^{-1}
As	145 µg g^{-1}	9 µg g^{-1}	111 µg g^{-1}	6 µg g^{-1}	258 µg g^{-1}	39 µg g^{-1}
Au	1.28 mg g^{-1}	0.09 mg g^{-1}	552 µg g^{-1}	37 µg g^{-1}	1.41 mg g^{-1}	0.14 mg g^{-1}
Ba	18.0 mg g^{-1}	0.7 mg g^{-1}	20.3 mg g^{-1}	0.9 mg g^{-1}	19.0 mg g^{-1}	1.9 mg g^{-1}
Be	1.8 µg g^{-1}	0.4 µg g^{-1}	*< LOQ*		0.8 µg g^{-1}	0.2 µg g^{-1}
Bi	53.8 µg g^{-1}	2.1 µg g^{-1}	15.5 µg g^{-1}	0.5 µg g^{-1}	39 µg g^{-1}	14 µg g^{-1}
Ca	9.48 mg g^{-1}	0.16 mg g^{-1}	8.34 mg g^{-1}	0.20 mg g^{-1}	12.3 mg g^{-1}	2.7 mg g^{-1}
Cd	1.7 µg g^{-1}	0.6 µg g^{-1}	0.9 µg g^{-1}	0.5 µg g^{-1}	0.6 µg g^{-1}	0.4 µg g^{-1}
Co	0.50 mg g^{-1}	0.20 mg g^{-1}	0.27 mg g^{-1}	0.13 mg g^{-1}	0.54 mg g^{-1}	0.14 mg g^{-1}
Cr	123 µg g^{-1}	5 µg g^{-1}	0.65 mg g^{-1}	0.18 mg g^{-1}	42 mg g^{-1}	7 mg g^{-1}
Cu	371 mg g^{-1}	9 mg g^{-1}	494 mg g^{-1}	10 mg g^{-1}	306 mg g^{-1}	26 mg g^{-1}
Fe	157.2 mg g^{-1}	3.2 mg g^{-1}	18.9 mg g^{-1}	1.0 mg g^{-1}	251 mg g^{-1}	24 mg g^{-1}
Ga	180 µg g^{-1}	21 µg g^{-1}	103 µg g^{-1}	12 µg g^{-1}	267 µg g^{-1}	37 µg g^{-1}
Ge	12.4 µg g^{-1}	3.2 µg g^{-1}	3.9 µg g^{-1}	1.2 µg g^{-1}	20 µg g^{-1}	6 µg g^{-1}
Hf	17.9 µg g^{-1}	1.5 µg g^{-1}	28.2 µg g^{-1}	2.0 µg g^{-1}	23 µg g^{-1}	4 µg g^{-1}
Hg	*< LOQ*		*< LOQ*		0.34 µg g^{-1}	0.29 µg g^{-1}
In	141 µg g^{-1}	10 µg g^{-1}	144 µg g^{-1}	11 µg g^{-1}	134 µg g^{-1}	52 µg g^{-1}
Li	35.2 µg g^{-1}	1.1 µg g^{-1}	36.9 µg g^{-1}	0.8 µg g^{-1}	40.5 µg g^{-1}	1.7 µg g^{-1}
Mg	0.701 mg g^{-1}	0.018 mg g^{-1}	2.00 mg g^{-1}	0.05 mg g^{-1}	1.68 mg g^{-1}	0.32 mg g^{-1}
Mn	2.407 mg g^{-1}	0.037 mg g^{-1}	0.48 mg g^{-1}	0.07 mg g^{-1}	4.9 mg g^{-1}	0.5 mg g^{-1}
Mo	244 µg g^{-1}	28 µg g^{-1}	75 µg g^{-1}	10 µg g^{-1}	265 µg g^{-1}	35 µg g^{-1}
Na	412 µg g^{-1}	27 µg g^{-1}	391 µg g^{-1}	35 µg g^{-1}	0.40 mg g^{-1}	0.20 mg g^{-1}
Nb	44 µg g^{-1}	19 µg g^{-1}	9.5 µg g^{-1}	1.6 µg g^{-1}	32 µg g^{-1}	8 µg g^{-1}
Ni	41.5 mg g^{-1}	1.8mg g^{-1}	82.9 mg g^{-1}	2.8 mg g^{-1}	57 mg g^{-1}	10 mg g^{-1}
Pb	283 µg g^{-1}	16 µg g^{-1}	597 µg g^{-1}	22 µg g^{-1}	0.61 mg g^{-1}	0.16 mg g^{-1}
Pd	99 µg g^{-1}	5 µg g^{-1}	100 µg g^{-1}	4 µg g^{-1}	178 µg g^{-1}	19 µg g^{-1}
Pt	7.3 µg g^{-1}	1.1 µg g^{-1}	5.3 µg g^{-1}	1.2 µg g^{-1}	25 µg g^{-1}	5 µg g^{-1}
Rb	0.8 µg g^{-1}	0.3 µg g^{-1}	0.7 µg g^{-1}	0.1 µg g^{-1}	0.010 µg g^{-1}	0.008 µg g^{-1}
Sb	12.2 µg g^{-1}	1.6 µg g^{-1}	3.16 µg g^{-1}	1.36 µg g^{-1}	9.8 µg g^{-1}	5.9 µg g^{-1}
Si	60.0 mg g^{-1}	1.7 mg g^{-1}	45.3 mg g^{-1}	1.5 mg g^{-1}	80.2 mg g^{-1}	2.1 mg g^{-1}
Sn	38.1 mg g^{-1}	1.1 mg g^{-1}	41.7 mg g^{-1}	1.8 mg g^{-1}	31.4 mg g^{-1}	2.9 mg g^{-1}
Sr	284 µg g^{-1}	5 µg g^{-1}	372 µg g^{-1}	10 µg g^{-1}	233 µg g^{-1}	62 µg g^{-1}
Ta	2.80 mg g^{-1}	0.24mg g^{-1}	2.33 mg g^{-1}	0.07 mg g^{-1}	2.0 mg g^{-1}	0.7 mg g^{-1}
Te	*< LOQ*		1.5 µg g^{-1}	0.9 µg g^{-1}	*< LOQ*	
Ti	6.45 mg g^{-1}	0.26 mg g^{-1}	7.30 mg g^{-1}	0.31 mg g^{-1}	7.1 mg g^{-1}	0.5 mg g^{-1}

Table 4 continued

	Smartphone I		Smartphone II		Smartphone III	
Element	Mass fraction (*n* = 3)	u_c	Mass fraction (*n* = 3)	u_c	Mass fraction (*n* = 3)	u_c
Tl	< *LOQ*		0.2 µg g^{-1}	0.1 µg g^{-1}	0.8 µg g^{-1}	0.5 µg g^{-1}
V	140 µg g^{-1}	9 µg g^{-1}	12.8 µg g^{-1}	0.7 µg g^{-1}	187 µg g^{-1}	30 µg g^{-1}
W	1.11 mg g^{-1}	0.10 mg g^{-1}	1.74 mg g^{-1}	0.07 mg g^{-1}	0.86 mg g^{-1}	0.11 mg g^{-1}
Zn	3.77 mg g^{-1}	0.16 mg g^{-1}	69 mg g^{-1}	5 mg g^{-1}	5.6 mg g^{-1}	1.0 mg g^{-1}
Zr	692 µg g^{-1}	28 µg g^{-1}	1.28 mg g^{-1}	0.05 µg g^{-1}	0.91 mg g^{-1}	0.13 mg g^{-1}
REE:						
Ce	1.7 µg g^{-1}	1.2 µg g^{-1}	2.1 µg g^{-1}	0.8 µg g^{-1}	4.9 µg g^{-1}	1.6 µg g^{-1}
Dy	189 µg g^{-1}	24 µg g^{-1}	170 µg g^{-1}	21 µg g^{-1}	163 µg g^{-1}	37 µg g^{-1}
Er	0.2 µg g^{-1}	0.05 µg g^{-1}	4.1 µg g^{-1}	0.5 µg g^{-1}	1.55 µg g^{-1}	0.22 µg g^{-1}
Eu	1.16 µg g^{-1}	0.15 µg g^{-1}	1.38 µg g^{-1}	0.18 µg g^{-1}	1.03 µg g^{-1}	0.12 µg g^{-1}
Gd	<*LOQ*		<*LOQ*		0.7 µg g^{-1}	0.3 µg g^{-1}
Ho	27 µg g^{-1}	16 µg g^{-1}	27.0 µg g^{-1}	3.3 µg g^{-1}	61 µg g^{-1}	16 µg g^{-1}
La	4.6 µg g^{-1}	2.3 µg g^{-1}	2.9 µg g^{-1}	0.5 µg g^{-1}	6.3 µg g^{-1}	1.3 µg g^{-1}
Lu	5.3 µg g^{-1}	0.9 µg g^{-1}	0.04 µg g^{-1}	0.01 µg g^{-1}	47 ng g^{-1}	12 ng g^{-1}
Nd	0.26 mg g^{-1}	0.07 mg g^{-1}	26 µg g^{-1}	28 µg g^{-1}	0.79 mg g^{-1}	0.31 mg g^{-1}
Pr	<*LOQ*		<*LOQ*		0.07 mg g^{-1}	0.05 mg g^{-1}
Sc	11 µg g^{-1}	5 µg g^{-1}	17.0 µg g^{-1}	2.7 µg g^{-1}	12.4 µg g^{-1}	2.5 µg g^{-1}
Sm	0.7 µg g^{-1}	0.7 µg g^{-1}	0.6 µg g^{-1}	0.7 µg g^{-1}	4.1 µg g^{-1}	2.1 µg g^{-1}
Tb	1.06 µg g^{-1}	0.36 µg g^{-1}	61 ng g^{-1}	32 ng g^{-1}	0.8 µg g^{-1}	0.4 µg g^{-1}
Tm	0.05 µg g^{-1}	0.02 µg g^{-1}	25 ng g^{-1}	5 ng g^{-1}	46 ng g^{-1}	10 ng g^{-1}
Y	43 µg g^{-1}	7 µg g^{-1}	0.23 mg g^{-1}	0.04 mg g^{-1}	40 µg g^{-1}	15 µg g^{-1}
Yb	0.61 µg g^{-1}	0.22 µg g^{-1}	171 ng g^{-1}	30 ng g^{-1}	0.19 µg g^{-1}	0.05 µg g^{-1}
Number of determined elements	52		54		56	
Loss on ignition at 550°C (*w*/*w*)* / %	11.4		11.2		8.6	

*Loss on Ignition (LOI) of the PCB at 550°C shows on average 9-11 % weight loss. 550°C is the standard temperature used to estimate loss of organic and inorganic carbon (Dean. 1974; Hoornweg & Bhada. Tat. 2012). Heavy in metals with low melting points can already oxidize at this temperature (e.g. In, Li, Sn, Pb) increasing the weight. LOI is used as an indication for plastics components.

Literature:

W.E. Dean. 1974. J Sediment Petrol 44: 242-248

D. Hoornweg. P. Bhada-Tata. 2012. What a Waste: A Global Review of Solid Waste Management. Urban development series; knowledge papers no. 15. World Bank. Washington. DC.

ESI Table 5: Range of total metal amount in entire PCB from smartphone manufacturers (n = 3) in g (see also Figure 2). Uncertainties (u_c) correspond to total combined uncertainties (k = 1). Total weight of measured elements, weight of the PCB and the relative mass fraction are given in the last rows.

Element	Smartphone I		Smartphone II		Smartphone III	
	Total amount (n = 3) / g	u_c /g	Total amount (n = 3) / g	u_c / g	Total amount (n = 3) / g	u_c / g
Ag	0.0052	0.0018	0.0083	0.0021	0.0037	0.0008
Al	0.305	0.009	0.394	0.011	0.130	0.033
As	0.00176	0.00011	0.00254	0.00014	0.0031	0.0005
Au	0.0156	0.0011	0.0125	0.0009	0.0173	0.0018
Ba	0.219	0.009	0.460	0.020	0.233	0.023
Be	0.00002	0.00001	< *LOQ*		0.00001	< 0.00001
Bi	0.00065	0.00003	0.00035	0.00001	0.00048	0.00017
Ca	0.1152	0.0019	0.1898	0.0046	0.150	0.033
Cd	0.00002	0.00001	0.00002	0.00001	< 0.00001	< 0.00001
Co	0.0061	0.0024	0.0062	0.0030	0.0067	0.0017
Cr	0.00150	0.00006	0.0149	0.0041	0.51	0.09
Cu	4.51	0.11	11.24	0.22	3.75	0.32
Fe	1.910	0.039	0.429	0.022	3.08	0.30
Ga	0.00219	0.00026	0.00234	0.00028	0.0033	0.0005
Ge	0.00015	0.00004	0.00009	0.00003	0.00025	0.00007
Hf	0.00021	0.00002	0.00064	0.00004	0.00027	0.00005
Hg	< *LOQ*		< 0.00001	< 0.00001	< 0.00001	< 0.00001
In	0.00171	0.00012	0.00327	0.00024	0.00165	0.00064
Li	0.00043	0.00001	0.00084	0.00002	0.00050	0.00002
Mg	0.00852	0.00022	0.0454	0.0011	0.021	0.0040
Mn	0.0293	0.0005	0.0108	0.0015	0.061	0.007
Mo	0.00297	0.00034	0.00171	0.00023	0.0032	0.0004
Na	0.00500	0.00032	0.0089	0.0008	0.0049	0.0024
Nb	0.00054	0.00023	0.00022	0.00004	0.00039	0.00010
Ni	0.504	0.021	1.887	0.065	0.69	0.12
Pb	0.00344	0.00019	0.0136	0.0005	0.0074	0.0019
Pd	0.00120	0.00005	0.00228	0.00010	0.00218	0.00023
Pt	0.00009	0.00001	0.00019	0.00003	0.00031	0.00006
Rb	0.00001	< 0.00001	0.00002	< 0.00001	< 0.00001	< 0.00001
Sb	0.00015	0.00002	0.00007	0.00003	0.00012	0.00007
Si	0.730	0.021	1.031	0.033	0.984	0.025
Sn	0.462	0.014	0.949	0.040	0.38	0.036
Sr	0.00345	0.00006	0.00847	0.00023	0.0029	0.0008
Ta	0.0341	0.0029	0.0530	0.0016	0.024	0.009
Te	< *LOQ*		0.00003	0.00002	< *LOQ*	
Ti	0.0784	0.0032	0.1658	0.0071	0.087	0.007
Tl	< *LOQ*		< 0.00001	< 0.00001	< 0.00001	< 0.00001
V	0.00170	0.00011	0.00029	0.00002	0.00229	0.00037
W	0.0135	0.0013	0.0397	0.0016	0.0105	0.0014
Zn	0.0458	0.0020	1.57	0.10	0.0687	0.0129

Table 5 continued

Element	Smartphone I		Smartphone II		Smartphone III	
	Total amount (*n*= 3) / g	u_c /g	Total amount (*n*= 3) / g	u_c / g	Total amount (*n*= 3) / g	u_c / g
Zr	0.00841	0.00034	0.0291	0.0010	0.0111	0.0016
REE	0.0067	0.0009	0.0110	0.0014	0.0140	0.0097
Sum weigth of elements /g	9.03667		18.59945		10.28331	
Weight of entire PCB / g	12.15242 ± 0.00001		22.75713 ± 0.00001		12.26893 ±0.00001	
Metal fraction of total PCB / %	74		82		84	

ESI Table 6: Within model variability and within device variability of the total amounts of elements determined in PCB (without metal covers and contacts) from model Smartphone I. Data with relative standard deviation (*RSD*).

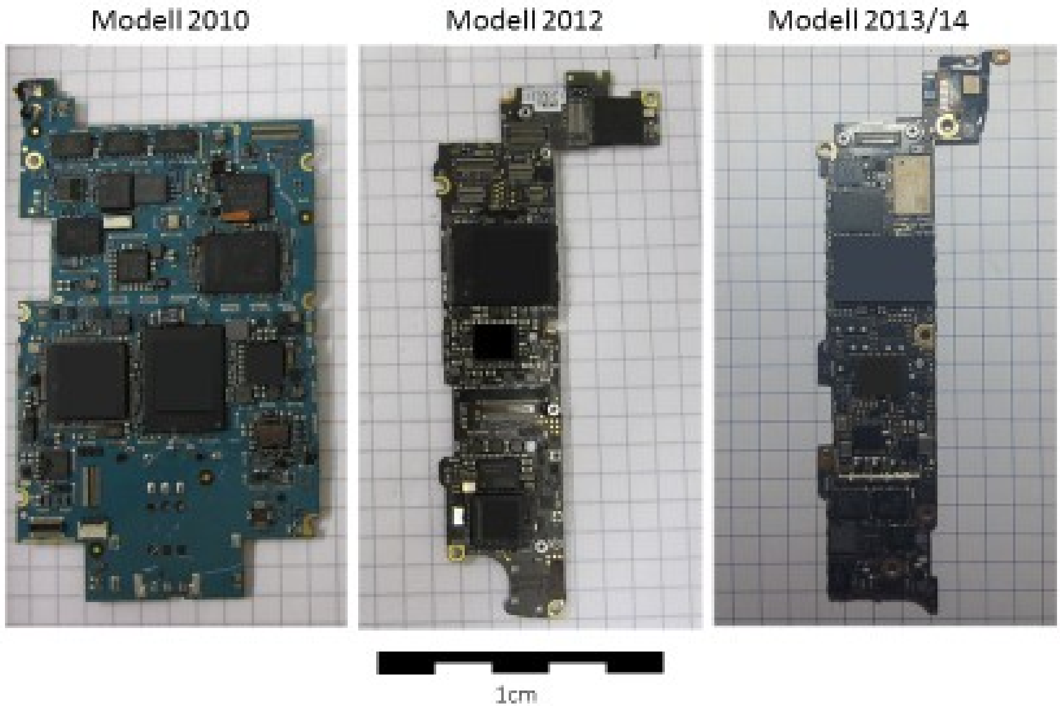
Element	Smartphone I (average from a, b, c)		Smartphone Ia		Smartphone Ib		Smartphone Ic	
	average (*n*=3) / g	*RSD* / %	average (*n*=3) / g	*RSD* / %	average (*n*=3) / g	*RSD* / %	average (*n*=3) / g	*RSD* / %
Ag	0.0050	16	0.0052	44	0.0041	35	0.0056	24
Al	0.306	22	0.353	2	0.336	2	0.228	2
As	0.0017	26	0.0019	6	0.00119	3	0.00204	2
Au	0.0147	3	0.0146	11	0.0144	6	0.01517	2
Ba	0.219	5	0.229	2	0.218	3	0.2089	1
Be	0.00002	7	0.00002	15	0.00002	10	0.00002	39
Bi	0.00065	5	0.00067	0	0.00062	3	0.00068	5
Ca	0.115	4	0.1153	1	0.1201	2	0.1100	1
Cd	0.00001	3	0.00001	39	0.00001	29	0.00001	35
Co	0.0020	5	0.00195	10	0.0021	31	0.0019	76
Cr	0.00150	2	0.00154	5	0.00147	0	0.00148	6
Cu	4.30	6	4.08	3	4.235	1	4.58	3
Fe	0.267	6	0.286	2	0.2623	1	0.253	2
Ga	0.00154	24	0.00161	1	0.00114	5	0.00186	3
Ge	0.00013	5	0.00013	7	0.00012	26	0.00014	3
Hf	0.00021	4	0.00021	8	0.00022	3	0.00021	7
In	0.00167	2	0.00168	2	0.00164	2	0.00170	3
Li	0.00043	2	0.00042	3	0.00044	3	0.00043	3
Mg	0.009	24	0.00736	2	0.00727	3	0.01093	2
Mn	0.0035	4	0.00360	2	0.00361	1	0.00339	2
Mo	0.00124	7	0.00121	12	0.00134	3	0.00118	19
Na	0.00496	10	0.00553	6	0.00472	6	0.00465	5
Nb	0.00013	19	0.00013	26	0.00011	14	0.00016	59
Ni	0.3079	1	0.310	3	0.303	2	0.310	3
Pb	0.00335	6	0.00332	6	0.00317	3	0.00356	6
Pd	0.00116	1	0.00117	7	0.00115	2	0.00118	1
Pt	0.00009	6	0.00009	18	0.00009	18	0.00008	6
Rb	0.00001	23	0.00001	35	0.00001	43	0.00001	19
Sb	0.00013	9	0.00014	7	0.00011	16	0.00013	16
Si	0.714	2	0.707	3	0.703	2	0.734	2
Sn	0.452	4	0.441	2	0.443	1	0.472	3
Sr	0.00345	2	0.00353	0	0.00340	2	0.00342	2
Ta	0.0337	10	0.038	19	0.0314	2	0.0320	2
Ti	0.0729	2	0.0739	2	0.0709	1	0.07366	2
V	0.00013	12	0.00013	7	0.00014	2	0.00011	4
W	0.0130	12	0.0136	6	0.0112	7	0.0142	15

Table 6 continued

	Smartphone I (average from a, b, c)		Smartphone Ia		Smartphone Ib		Smartphone Ic	
	average (n = 3) / g	*RSD* / %	average (n = 3) / g	*RSD* / %	average (n = 3) / g	*RSD* / %	average (n = 3) / g	*RSD* / %
Zn	0.0458	15	0.0524	9	0.0461	1	0.0388	2
Zr	0.00841	4	0.00805	1	0.00876	3	0.00841	3
REE	0.0067	16	0.0079	11	0.00629	6	0.0059	8
weight PCB* / g	9.82102	1	9.66088 ± 0.00001		9.86501 ± 0.00001		9.93718 ± 0.00001	

*PCB without metal covers and contacts

ESI Figure 1: Comparison of PCB from consecutive smartphones models of the same brand. Between 2010 and 2012, resource efficiency and miniaturization of PCB is clearly visible. Since 2012, PCB design have not changed significantly. This underlines that we investigated a representative PCB of newer smartphone generations.



ESI Figure 2: Schematics of the procedure to investigate within-device and within-model variability.