

E-waste Report

Determination of regulated elements in seven types of discarded consumer electronic products

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Executive Summary

At the request of the DTSC Regulatory Program and Development Division (RPDD), Hazardous Waste Management Program, the Hazardous Materials Laboratory (HML) arranged for the testing of selected waste electronic devices (e-waste) to determine the total and extractable concentrations of regulated elements for comparison with hazardous waste criteria. Seven electronic product types (microwave ovens, VCRs, printers, CPUs, cell phones, telephones, and radios) were identified and, from each product type, four devices of various brands and models were collected by RPDD and submitted for analysis.

A protocol was developed to address the particular challenges of the e-waste samples. Devices were dismantled individually, and components classified into millable parts (plastic casings and printed circuit boards without capacitors or batteries), and non-millable parts (metal frames, rods, capacitors, batteries and other metal parts). The weights of the millable and non-millable components were recorded. All millable components were ground to pass a 2mm sieve and mixed well. Representative sub-samples were digested using EPA Method 3050, or extracted using the Toxicity Characteristic Leaching Procedure (TCLP), or extracted using the California Waste Extraction Test (WET). Results were extrapolated to the entire device based on relative weights and with the assumption that non-millable components did not contain any regulated elements.

Results indicate that all the product types tested clearly exceeded at least one hazardous waste criterion. Lead was the most common element exceeding its limits.

Introduction

At the request of the Regulatory Program and Development Division (RPDD), Hazardous Waste Management Program, the Hazardous Materials Laboratory (HML) arranged for the testing of electronic devices to determine the total and soluble concentrations of regulated elements for comparison with hazardous waste criteria in Title 22, Chapter 11, Article 3. Specific testing performed on the electronic devices were the Toxicity Characteristic Leaching Procedure (TCLP); California Waste Extraction Test (WET), and EPA Method 3050 followed by elemental testing. The results of these analytical tests were compared to hazardous waste regulatory thresholds for each analytical test: the Toxicity Characteristic regulatory level, the Soluble Threshold Limit Concentrations and Total Threshold Limit Concentrations, respectively.

Chemical analysis of e-wastes presents challenges because of the physical nature of these devices (size, composition), and the potential heterogeneity within devices and between devices. A protocol was prepared to measure this heterogeneity, by testing four devices of seven different product types, plus testing selected devices in triplicate to measure within-sample heterogeneity.

Materials and Methods

Seven product types were identified for this project and, from each product type, four devices of different brands and models were collected by RPDD and submitted for analysis. The twenty eight devices are listed in Table 1. These devices were delivered by RPDD to Sequoia Analytical Laboratories in Morgan Hill, CA where work was performed under contract # 02-T2409 under the oversight of DTSC.

Sample Preparation:

The Standard Operating Procedure (HML SOP#733-S) developed for this project is shown in Appendix A. In summary, the 28 devices were dismantled individually, and components classified into two major types:

- 1) Millable (plastic components, plastic casings, printed circuit boards-without any batteries or capacitors), and
- 2) Non millable metal components (metal frames, rods, batteries, capacitors and other metal parts.).

All millable components were cut into small pieces and ground using a heavy duty mill (Retsch, Model #SM-2000) to achieve the desired particle size and passed through a 2mm mesh sieve. The laboratory used a 2 mm sieve for all analyses (total extractable concentrations, WET and TCLP) instead of the 1mm, 2mm and 9.5mm sieves specified in the respective test procedures. The deviation was necessary because of the limited mass of some samples. Another deviation from the SOP was the use of plastic chips instead of wood chips to clean the milling apparatus and serve as blanks to determine cross contamination. HML accepted this deviation because plastic chips were similar to the samples, and worked better in the grinder. Milled samples were thoroughly mixed to achieve homogeneity before removing aliquots for testing.

Sample Digestion for Elemental Testing:

A one gram (1 g) representative sub-sample of the thoroughly mixed sample was digested using EPA Method 3050B, with repeated additions of nitric acid, hydrochloric acid and hydrogen peroxide till the digestion was complete.

Extraction Procedures:

Sub-samples were taken from the milled samples and were extracted using the TCLP and the WET to determine the leachability potential of regulated elements.

TCLP: An aliquot of the sample was extracted as described in EPA Method 1311. Samples were extracted with an amount of extraction fluid equal to 20 times the weight of the sample. The extraction fluid employed is a function of alkalinity of the sample. Extraction fluid #1, consisting of a mixture of acetic acid and sodium hydroxide at pH 4.93 +/- 0.05, was used, since the final pH of the samples after the addition of 1N HCl was <2.0. The extraction vessel containing the sample and the extraction fluid was agitated on a rotary shaker at 30 +/- 2 rpm for 18 +/- 2 hours at ambient temperature. The material in the extraction vessel was filtered through a glass fiber filter (0.45 micron) and the liquid extract was preserved with nitric acid to 5% by volume until ready for digestion and analysis.

WET: Sample aliquots were extracted with a citrate buffer solution (10 times the weight of the sample) at pH 5.0 for 48 hours in a mechanical shaker under anaerobic conditions. Mixtures were centrifuged, filtered through Whatman filter paper #42 and then passed through 0.45 micron membrane filter. The extracts were preserved by acidifying with nitric acid to 5% by volume before digestion and analysis.

Analytical Procedure:

The above prepared samples were digested with nitric acid, hydrochloric acid, and hydrogen peroxide, as specified in EPA Method 3050B. The digestates were analyzed by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP –AES, Thermo Jarrell Ash, Model 61E), using EPA method 6010B. According to this method, digested samples were filtered through 0.45 micron membrane filters, nebulized and the resulting aerosol transported into the plasma torch. Emission spectra were produced by radio frequency, dispersed by the grating material and the intensities of the emission lines were measured by photosensitive devices.

Quality Control:

A unique quality assurance program was adopted to ensure the reliability of the data. Before milling the samples, plastic chips that had been washed with nitric acid were run through the milling apparatus. These blanks were analyzed to demonstrate that the milling operation was free of cross-contamination.

A sample batch was defined as a group of 10 samples, or fewer, processed together with appropriate QC samples. With each batch of samples one method blank, one laboratory control sample (LCS) prepared in DI water, one matrix spike (MS) and one matrix spike duplicate (MSD) sample were analyzed. Between batches, plastic chips

were processed to confirm absence of cross-contamination. One sample of each product type, with the exception of the CPU, was extracted and analyzed in triplicate for total elements to examine the homogeneity and the precision of the data.

Results

Data Management

The elemental concentrations measured in the milled portions of the devices were converted to concentrations in the entire device by using the relative weights (Table 1), with the assumption that the unmilled portion of each device did not contain any of the regulated elements.

Analytical results are shown in Tables 2-5. All 28 samples were analyzed for EPA Method 3050 concentrations, TCLP-extractable elements and WET-extractable elements, with the exception of sample #18 (cell phone) which was not extracted using the TCLP, and sample #20 (telephone) which was not analyzed for either WET- or TCLP-extractable elements because of insufficient weight. These results are shown as not analyzed, "NA" in the respective tables. Data marked "NA" were not used in calculations, and summary statistics were performed on the remainder of the set, i.e., on three rather than four devices. Data below the reporting limit are shown as not detected, "ND". Reporting limits varied with dilution factors. Nevertheless, they were always significantly lower than the respective hazardous waste criteria. When only one value for a particular element among the four samples (or three, in the case of replicate analysis) was "ND", that value was replaced by one-half of its respective reporting limit (adjusted for any dilution factor). These estimated values and the summary statistics that use such values are highlighted with a gray background in Tables 2-5. When more than one value among the four samples (or three, in the case of replicate analysis) was "ND", no adjustments were made and no summary statistics were performed for that particular element. In this case, whereas individual values are reported, the data are not used in determining summary statistics.

Tables 2-5 show results for individual samples plus the arithmetic average (mean) of all samples in the product type, coefficient of variation (CV %) and the upper confidence level (UL) for the mean (1-sided, 90th percentile). Entries in bold face (individual result, mean or UL) indicate results exceeding the respective regulatory thresholds (shown on the first row). The coefficient of variation in Table 2 expresses the variability observed among the four samples of each product type. CVs in Table 3 reflect the within-sample variation.

Quality Control Results:

Quality Control (QC) results for Total Extractable Concentrations are shown in Appendix B (Table QC-1). Samples were digested and analyzed separately in 9 batches. Samples # 5, 19, 20 and 28 were used as Matrix Spikes and Matrix Spike Duplicates (MS/MSD). Samples were spiked with all the elements at 50 mg/kg concentrations along with the Laboratory Control Samples (LCSs) spiked at the same level (50 mg/L) in de-ionized water. Method blanks and reagent blanks were analyzed in between the actual samples

and the QC samples, to assess any carryover from high level background concentrations. None of the elements were detectable in the plastic chip blanks, indicating that the milling system was free of cross contamination. In all the batches, recovery of LCS ranged from 84% to 103%. However, recoveries in MS/MSD varied from element to element because some of the elements such as Pb, Cu, Zn, Sb, Co and Ni were present at very high concentrations compared to the amount spiked. Nevertheless, overall recoveries ranged from 77.6% to 109 %.

For WET-extractable elements, samples were analyzed in four (4) batches with method blanks and LCSs. MS/MSDs were run on samples # 1, 7, 8, 10, 20 (Appendix B, Table QC-II). These, and an equal number of LCSs, were spiked with all the elements at a concentration of 2mg/L. LCS recoveries varied from 88.5% to 114% and all method blanks were below detection. MS and MSD were recovered within the range of 82% to 118%. Recoveries of Pb, Co and Zn, however, were not reported in some batches due to high background concentrations in comparison to the spike concentrations.

TCLP analysis was batched into five sets of samples with method blanks and LCS (Appendix B, Table QC-III). These batches included other samples (soils from a separate project) in addition to the e-wastes and, therefore, relevant MS/MSDs were performed on samples #1, 7 and 8 only. Samples and LCS were spiked at 0.8 mg/L with seven regulated elements only. None of the elements was detected in method blanks, and LCS recoveries ranged from 88% to 112% except for Ba, which showed around 200% recovery. MS and MSD recoveries varied from 85% to 113%, with the exception of Pb and Ba which were not reported due to very wide limits, attributable to the high concentrations in the samples.

To assess the homogeneity of the samples subjected to analysis, six devices (# 1, 5, 13, 19, 20 and 28) were analyzed in triplicate. Table 3 shows the individual results, their mean, standard deviation and coefficient of variation of these triplicate analyses. CVs ranged from 4% (Cu in telephones, and Sb in cell phones) to 134% (Cr in VCR). The standard error of the mean (se) is shown in Table 3 and is plotted in Figures 1-3.

Total Concentrations

Table 2 shows the results for total concentrations in mg/Kg (extrapolated to the entire device using the relative weights of millable and non-millable portions) for all samples. TTLCs are shown in the top row. It is clear that only a few elements (Sb, Cu and Pb) were consistently measured in all samples. Cell phones had the most measurable elements, with many elements above the respective TTLC. Figures 1-3 show measurements for Pb, Cu and Sb in each product type. The dark solid bar represents the mean concentration of the four devices within each product type and the error bar represents the 90% UL. The TTLC drawn in these figures allows a visual comparison of the 90% UL to the respective TTLC. Figures 1-3 also show the results of the triplicate analyses for the same elements. The light solid bar represents the mean concentration of the three replicates of each device. The error bar in this case is the standard error of the mean, expressing the observed variability.

TCLP

TCLP results (mg/L extrapolated to the entire device) are shown in Table 4. Only Pb was measured consistently across devices. Figure 4 shows the mean Pb concentrations, the 90% UL and the TCLP limit. All product types, except for the Microwaves, appear to fail the TCLP for Pb.

WET

Table 5 shows WET-extractable results in mg/L (extrapolated to the entire device). Cu, Pb and Zn were measurable in many devices. All product types except for the CPU exceeded the STLC for Pb. Figures 5 and 6 show results for Pb and Zn, respectively.

Table 6 summarizes the product types that exceed the TTLCs, TC Limits, or STLCs. It is clear that all product types exceeded at least one of the regulatory thresholds. All product types exceed the TCLP limit for Pb and, with the exception of CPUs, all product types exceed the STLC for Pb. Cell phones have the most exceedences and microwaves the fewest: Cell phones exceed both the STLC and TCLP limits for Pb, and they also exceed the TTLC for Pb, Sb, Cu, Ni and Cr. Microwaves only exceed the STLC for Pb.

Discussion

HML assessed the homogeneity of samples processed through the grinder by conducting triplicate analyses for Total Metals on six of the seven product types (one device from each product type, except for the CPU). As can be seen in Table 3, relative coefficient of variation (%CV) varied across devices and elements. The lowest %CVs were obtained for Cu (4% to 48%), Sb (4% to 51%) and Pb (19% to 56%) measured in all six devices. As these were the metals consistently measured above the respective criteria in most devices, it is reassuring to see that samples were reasonably homogeneous and that our conclusions apply.

Lead was the only element where both the TCLP-extractable and the WET-extractable concentrations were consistently measured in most devices. The summary in Table 6 shows that the 90% UL of results for each device exceed at least one hazardous waste criterion. Elements marked with an asterisk indicate that, whereas the 90%UL exceeded the respective regulatory limit, the number of samples tested (n=4) was inadequate, given the observed variation, the difference between the mean value and the regulatory limit, and assuming a normal distribution. For these types of devices, additional samples are needed to evaluate these particular elements. Specifically, with the observed variation, 24 samples are needed to confidently determine whether the TTLC is exceeded for Pb in printers. On the other hand, 11 samples are needed to determine whether the TTLC is exceeded for Sb in printers. Similarly, 18 samples are needed to determine whether the TTLC is exceeded for Cr and over 300 samples are needed for Ni in cell phones. Nine samples are required for Ni in telephones and 11 samples are required for Sb in radios. All other determinations had adequate sample size. Even if the elements that require additional measurements are disregarded, all product types exceed at least one hazardous waste criterion.

As discussed in this report, there are some other considerations for waste classification. First, there is the issue of sample preparation. The contract laboratory milled all samples to pass a 2 mm sieve, although the TCLP specifies a 9.5 mm sieve, and the preparation for Total Concentrations testing specifies a 1 mm sieve. This deviation from the prescribed particle size could have a significant effect on the TCLP results; however, the TCLP only specifies that the waste is milled to pass a 9.5 mm sieve and does not preclude milling to a smaller size. Since the correct sieve size was used for the WET, there is more confidence in the results showing that microwave ovens significantly exceed the STLC. For other devices, the particle size does not appear to have any significant effect on whether the regulatory thresholds are exceeded, as all results clearly exceed hazardous waste regulatory thresholds.

In summary, all the devices tested, clearly exceeded at least one hazardous waste criterion (RCRA on non-RCRA). These results confirm our observations in the DTSC pilot study on E-wastes.

Conclusions

- All product types clearly exceeded at least one hazardous waste criterion.
- Lead was the most common element exceeding its limit.
- Cell phones exceeded the most regulatory thresholds compared to the other product types tested.
- With the exception of microwave ovens, all product types tested exceeded the TTLC and TCLP regulatory thresholds.
- With the exception of CPUs, all product types tested exceeded at least one STLC.

TABLE 1. List of 28 e-waste devices (type, manufacturer, model, serial number) and weights of components.

ID	Product Type	Manufacturer	Model No.	Serial No.	Wt. of Non-Metal parts (Kg)	Wt. of Metal parts (Kg)	Total Wt. of device (Kg)
1	Microwave Oven	GE Dual Wave II	JE1465001	DV91098Z	1.913	13.2	15.1
2	Microwave Oven	Montgomery Ward 1.5	KSA 8223A	149789	0.565	33.2	33.76
3	Microwave Oven	Sharp Carousel II	R4A83A	148866	1.297	14.7	16
4	Microwave Oven	JC Penny Microwave	863553570	71101269	1.259	19.7	21
5	VCR	SV2000 4Head	SVX142AT21	743329458	1.18	1.6	2.78
6	VCR	XR1000 4- Head	SVG451	S307602727	1.223	3.8	5.02
7	VCR	JVC	HR-D225U	119L1287	3.354	6.0	9.35
8	VCR	JVC	HR-D225U	9991724	3.341	6.8	10.14
9	CPU	AT&T PC	6300	154509	1.472	12.3	13.77
10	CPU	Packard Bell Multimedia	940-3X3A	N368021369	2.545	7.8	10.05
11	CPU	Cordata PC 400	PC-400-25	2BSA5532	1.773	11.1	12.87
12	CPU	Cordata PC 400	PC-400-25	2BSA6594	2.024	12.5	14.52
13	Printer	Star Micronics	J24140	3-4008E+11	1.705	2.0	3.7
14	Printer	Epson Stylus color 500	P880A	3BR1482700	1.822	4.2	6.02
15	Printer	Laxmark Z51	4098-001	7100078881	2.885	0.8	3.69
16	Printer	HP Desk Jet	2276A	2803A22999	1.647	1.8	3.45
17	Cell Phone	Motorola	52140AA	935VWFS76	0.178	0.3	0.478
18	Cell Phone	Motorola i1000 plus	H26UAH6RR7AN	831TBCD72M00504818513100	0.102	0.026	0.128
19	Cell Phone	Motorola	74202NTTOA	A55GYO6215	0.314	0.23	0.544
21	Cell Phone	Motorola i1000 plus	H26UAH6RR7AN	831TBCD75H0504818884100	0.115	0.09	0.205
20	Telephone	Sharp cordless phone/ Ans sys	FT-5410	50409471	0.433	0.163	0.596
22	Telephone	Sony High Power 900mhz	SPP-S9001	8251587	0.163	0.372	0.535
23	Telephone	ATT	1307	93202M	0.657	0.456	1.113
24	Telephone	Bell/South	1188	11111	0.22	0.062	0.282
25	Radio	Panasonic	RC-6063	-----	0.367	0.268	0.635
26	Radio	Realistic	12-150	30380043596	0.668	0.4	1.068
27	Radio	Magnavox	AJ3010/17	KT02960720 2005	0.348	0.175	0.523
28	Radio	General Electric	7-4630D	-----	0.732	0	0.732

TABLE 2. Concentrations of Total Concentrations in mg/kg of entire device. Bold face results indicate values above the respective TTLC (shown at the top of the Table.) Shaded cells indicate estimated values (1/2 of the reporting limit adjusted for dilution factor) and summary statistics using these estimated values. An asterisk indicates inadequate sample size.

TTLC =		500	10,000	75	100	2,500	8,000	2,500	1,000	3,500	2,000	100	500	700	2,400	5,000	
ID	DEVICE	Sb	As	Ba	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Ag	Tl	V	Zn
1	MW	4	ND	ND	ND	0.1	ND	ND	668	177	ND	87	ND	ND	ND	ND	371
2	MW	4	ND	ND	ND	1	ND	ND	853	52	ND	ND	ND	1	ND	ND	ND
3	MW	105	ND	ND	ND	24	3	ND	1,459	235	ND	26	ND	11	ND	ND	381
4	MW	16	ND	ND	ND	2	ND	ND	396	204	ND	ND	ND	ND	ND	ND	ND
mean		32	ND	ND	ND	7	ND	ND	844	167	ND	ND	ND	ND	ND	ND	ND
cv%		153	ND	ND	ND	174	ND	ND	53	48	ND	ND	ND	ND	ND	ND	ND
UL		72	ND	ND	ND	16	ND	ND	1,213	233	ND	ND	ND	ND	ND	ND	ND
5	VCR	1,542	ND	327	8	1.4	110	20	32,259	3,849	ND	454	ND	100	ND	ND	3,247
6	VCR	536	3	66	ND	ND	44	ND	13,887	2,680	10	731	ND	39	ND	ND	ND
7	VCR	610	4	ND	ND	1	1,004	32	46,633	5,381	ND	610	ND	43	ND	ND	6,457
8	VCR	758	ND	ND	ND	ND	8	ND	49,423	3,624	ND	112	ND	40	ND	ND	ND
mean		861	ND	ND	ND	ND	292	ND	35,550	3,883	ND	477	ND	55	ND	ND	ND
cv%		54	ND	ND	ND	ND	164	ND	46	29	ND	56	ND	54	ND	ND	ND
UL		1,241	ND	ND	ND	ND	682	ND	48,886	4,800	ND	696	ND	80	ND	ND	ND
9	CPU	256	ND	84	ND	1	8	6	11,733	3,093	ND	1,600	ND	33	ND	ND	ND
10	CPU	516	ND	269	ND	1	101	7	35,920	2,919	ND	247	ND	52	ND	ND	ND
11	CPU	481	4	371	ND	1	40	7	19,242	4,810	ND	1,086	ND	22	ND	ND	ND
12	CPU	405	4	391	ND	7	168	9	18,146	3,908	ND	698	ND	28	ND	ND	ND
mean		415	ND	279	ND	2	79	7	21,260	3,683	ND	908	ND	34	ND	ND	ND
cv%		28	ND	50	ND	123	89	15	49	24	ND	63	ND	38	ND	ND	ND
UL		509	ND	394	ND	5	137	8	29,712	4,393	ND	1,379	ND	44	ND	ND	ND
13	Printer	1,797	ND	184	ND	5	10	ND	10,276	1,765	ND	ND	ND	ND	ND	ND	1,198
14	Printer	1,998	ND	ND	ND	ND	163	ND	7,264	454	ND	236	ND	9	ND	ND	999
15	Printer	258	ND	ND	ND	ND	ND	ND	3,440	735	ND	ND	ND	ND	ND	ND	ND
16	Printer	35	ND	ND	ND	0	ND	ND	5,729	72	ND	220	ND	ND	ND	ND	ND
mean		1,022	ND	ND	ND	ND	ND	ND	6,677	756	ND	228	ND	ND	ND	ND	ND
cv%		100	ND	ND	ND	ND	ND	ND	43	96	ND	5	ND	ND	ND	ND	ND
UL		1,856*	ND	ND	ND	ND	ND	ND	9,026	1,350*	ND	237	ND	ND	ND	ND	ND

TABLE 2. Cont'd. Concentration of Total Concentrations in mg/kg of entire device. Bold face results indicate values above the respective TTLC (shown at the top of the Table.) Shaded cells indicate estimated values (1/2 of the reporting limit adjusted for dilution factor) and summary statistics using these estimated values. An asterisk indicates inadequate sample size.

ID	DEVICE	TTLC =																
		500	500	10,000	75	100	2,500	8,000	2,500	1,000	3,500	2,000	100	Se	Ag	TI	V	Zn
17	Cell	186	ND	1,862	130	ND	186	186	89,372	5,958	ND	1,862	ND	186	ND	ND	ND	ND
18	Cell	71	ND	606	ND	2	5,498	45	35,063	1,514	112	2,630	ND	77	ND	ND	ND	ND
19	Cell	808	6	904	117	3	22	319	8,466	4,656	ND	2,059	ND	160	ND	ND	ND	ND
21	Cell	168	ND	673	ND	ND	135	22	17,390	5,049	ND	954	ND	398	ND	ND	ND	ND
mean		308	ND	1,061	ND	ND	1,470	145	38,856	4,667	ND	1,946	ND	235	ND	ND	ND	ND
cv%		109	ND	57	ND	ND	184	97	97	45	ND	37	ND	67	ND	ND	ND	ND
UL		584	ND	1,487	ND	ND	3,666*	256	67,269	5,877	ND	2,446*	ND	317	ND	ND	ND	ND
20	Telephone	84	18	1,693	31	9	2,470	103	84,762	3,175	27	3,146	ND	186	49	ND	5,667	ND
22	Telephone	14	ND	85	ND	0.2	ND	ND	2,437	67	ND	30	ND	30	ND	ND	ND	ND
23	Telephone	401	ND	59	ND	7	ND	ND	30,695	2,420	ND	1,358	ND	18	ND	ND	2,597	ND
24	Telephone	94	ND	265	ND	8	ND	ND	31,206	3,043	ND	398	ND	8	ND	ND	ND	ND
mean		148	ND	526	ND	6	ND	ND	37,275	2,176	ND	1,233	ND	78	ND	ND	ND	ND
cv%		116	ND	149	ND	66	ND	ND	92	66	ND	113	ND	151	ND	ND	ND	ND
UL		290	ND	1,167	ND	9	ND	ND	65,444	3,359	ND	2,373*	ND	170	ND	ND	ND	ND
25	Radio	150	ND	185	ND	1	ND	ND	75,134	19,650	ND	ND	ND	127	ND	ND	ND	ND
26	Radio	751	ND	188	ND	3	21	24	112,584	20,015	ND	ND	ND	138	ND	ND	ND	ND
27	Radio	279	ND	67	ND	2	ND	ND	86,501	4,325	ND	ND	ND	43	ND	ND	ND	ND
28	Radio	279	ND	540	ND	6	ND	ND	71,000	4,433	ND	313	ND	16	ND	ND	280	ND
mean		365	ND	245	ND	3	ND	ND	86,305	12,106	ND	313	ND	81	ND	ND	280	ND
cv%		72	ND	84	ND	68	ND	ND	22	74	ND	ND	ND	75	ND	ND	ND	ND
UL		581*	ND	412	ND	5	ND	ND	101,624	16,510	ND	ND	ND	131	ND	ND	ND	ND

TABLE 3. Results of replicate analyses for Total Concentrations in mg/kg of entire device. Shaded cells indicate estimated values (1/2 of the reporting limit adjusted for dilution factor) and summary statistics using these estimated values.

ID	E-Waste Type	Sb	As	Ba	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Ag	Tl	V	Zn
1	MW	4.3	ND	ND	ND	ND	ND	ND	749	165	ND	88	ND	ND	ND	ND	292
1-R1		1.3	ND	ND	ND	ND	ND	ND	241	62	ND	ND	ND	ND	ND	ND	432
1-R2		5.6	ND	ND	ND	ND	ND	ND	1,016	305	ND	ND	ND	ND	ND	ND	394
mean		3.7	ND	ND	ND	ND	ND	ND	669	177	ND	ND	ND	ND	ND	ND	373
sd		1.8	ND	ND	ND	ND	ND	ND	321	99	ND	ND	ND	ND	ND	ND	59
cv%		49	ND	ND	ND	ND	ND	ND	48	56	ND	ND	ND	ND	ND	ND	16
se		1.0	ND	ND	ND	ND	ND	ND	186	57	ND	ND	ND	ND	ND	ND	34
5	VCR	1,230	ND	399	8	2	4	3	34,344	5,088	ND	102	ND	98	ND	ND	2,247
5 - R1		1,484	ND	157	ND	1	216	36	33,496	4,664	ND	806	ND	102	ND	ND	4,240
5 - R2		1,908	ND	424	ND	1	4	4	28,832	1,781	ND	42	ND	4	ND	ND	85
mean		1,541	ND	326	ND	1	75	15	32,224	3,844	ND	317	ND	68	ND	ND	2,191
sd		280	ND	120	ND	0	100	15	2,423	1,469	ND	347	ND	45	ND	ND	1,697
cv%		18	ND	37	ND	32	134	105	8	38	ND	109	ND	66	ND	ND	77
se		162	ND	69	ND	0	58	9	1,399	848	ND	200	ND	26	ND	ND	980
13	Printer	876	ND	207	ND	5	10	ND	10,142	2,028	ND	ND	ND	9	ND	ND	1,199
13-R1		2,489	ND	175	ND	4	5	ND	15,213	1,982	ND	ND	ND	ND	ND	ND	ND
13-R2		2,028	ND	175	ND	6	10	ND	5,532	1,291	ND	ND	ND	ND	ND	ND	ND
mean		1,798	ND	186	ND	5	8	ND	10,296	1,767	ND	ND	ND	ND	ND	ND	ND
sd		679	ND	15	ND	1	2	ND	3,954	337	ND	ND	ND	ND	ND	ND	ND
cv%		38	ND	8	ND	13	30	ND	38	19	ND	ND	ND	ND	ND	ND	ND
se		392	ND	9	ND	0	1	ND	2,283	195	ND	ND	ND	ND	ND	ND	ND
19	Cell	693	ND	924	133	0.3	17	45	69,265	3,001	ND	1,154	ND	127	ND	ND	ND
19 - R1		866	ND	750	110	2.9	23	104	86,581	6,926	ND	1,154	ND	190	ND	ND	ND
19 - R2		866	6	1,039	110	2.5	26	808	98,125	4,040	ND	3,867	ND	162	ND	ND	ND
mean		808	6	904	117	1.9	22	319	84,657	4,656	ND	2,059	ND	160	ND	ND	ND
sd		33	ND	144	4	0.5	2	361	7,284	1,520	ND	1,381	ND	17	ND	ND	ND
cv%		4	ND	16	4	27	9	113	9	33	ND	67	ND	11	ND	ND	ND
se		19	ND	83	3	0.3	1	208	4,206	878	ND	798	ND	10	ND	ND	ND
20	Phone	116	ND	1,744	7	ND	1,816	124	87,181	3,124	20	2,180	ND	102	ND	ND	2,615
20 - R1		80	ND	1,526	5	ND	218	27	79,916	2,252	7	2,180	ND	320	ND	ND	3,633
20 - R2		57	9	1,816	80	9	5,376	160	87,181	4,141	34	5,086	ND	312	49	ND	8,718
mean		85	ND	1,695	31	ND	2,470	103	84,760	3,172	20	3,148	ND	245	49	ND	4,989
sd		24	ND	123	35	ND	2,156	56	3,425	772	11	1,370	ND	101	0	ND	2,670
cv%		29	ND	7	114	ND	87	54	4	24	54	44	ND	41	0	ND	54
se		14	ND	71	20	ND	1,245	32	1,977	446	6	791	ND	58	0	ND	1,541

TABLE 3.cont'd. Results of replicate analyses for Total Concentrations in mg/kg of entire device. Shaded cells indicate estimated values (1/2 of the reporting limit adjusted for dilution factor) and summary statistics using these estimated values.

ID	E-Waste Type	Sb	As	Ba	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Ag	Tl	V	Zn
28	Radio	87	ND	100	ND	7	ND	ND	46,000	1,500	ND	100	ND	10	ND	ND	280
28 - R1		430	ND	840	ND	4	ND	ND	100,000	6,300	ND	240	ND	60	ND	ND	ND
28 - R2		320	ND	240	ND	7	ND	ND	67,000	5,500	ND	700	ND	31	ND	ND	ND
mean		279	ND	393	ND	6	ND	ND	71,000	4,433	ND	347	ND	34	ND	ND	ND
sd		143	ND	321	ND	2	ND	ND	22,226	2,100	ND	256	ND	20	ND	ND	ND
cv%		51	ND	82	ND	26	ND	ND	31	47	ND	74	ND	61	ND	ND	ND
se		83	ND	185	ND	1	ND	ND	12,832	1,212	ND	148	ND	12	ND	ND	ND

TABLE 4. Concentrations of TCLP- extractable elements in mg/L of entire device. Bold face results indicate values above the respective TCLP criteria (shown at the top of the Table.) Shaded cells indicate estimated values (1/2 of the reporting limit adjusted for dilution factor) and summary statistics using these estimated values.

ID	e-Waste Type	TCLP LIMIT=						
		5	100	1	5	5		
		As	Ba	Cd	Cr	Pb	Se	Ag
1	MW	ND	ND	ND	ND	1.7	ND	ND
2	MW	ND	ND	ND	ND	4.6	ND	ND
3	MW	ND	ND	ND	ND	4.3	ND	ND
4	MW	ND	ND	ND	ND	1.4	ND	ND
mean		ND	ND	ND	ND	3.0	ND	ND
cv%		ND	ND	ND	ND	56	ND	ND
UL		ND	ND	ND	ND	4.4	ND	ND
5	VCR	ND	ND	0.02	ND	55	ND	ND
6	VCR	ND	ND	ND	ND	21	ND	ND
7	VCR	ND	ND	0.00	ND	39	ND	ND
8	VCR	ND	ND	ND	ND	33	ND	ND
mean		ND	ND	ND	ND	37	ND	ND
cv%		ND	ND	ND	ND	38	ND	ND
UL		ND	ND	ND	ND	49	ND	ND
9	CPU	ND	ND	0.01	ND	50	ND	ND
10	CPU	ND	ND	0.00	ND	23	ND	ND
11	CPU	ND	ND	0.00	ND	60	ND	ND
12	CPU	ND	ND	0.01	ND	48	ND	ND
mean		ND	ND	ND	ND	45	ND	ND
cv%		ND	ND	ND	ND	36	ND	ND
UL		ND	ND	ND	ND	58	ND	ND
13	Printer	ND	ND	ND	ND	12	ND	ND
14	Printer	ND	ND	ND	ND	10	ND	ND
15	Printer	ND	ND	ND	ND	16	ND	ND
16	Printer	ND	ND	ND	ND	3	ND	ND
mean		ND	ND	ND	ND	10	ND	ND
cv%		ND	ND	ND	ND	54	ND	ND
UL		ND	ND	ND	ND	15	ND	ND

TABLE 4. Cont'd. Concentrations of TCLP- extractable elements in mg/L of entire device. Bold face results indicate values above the respective TCLP criteria (shown at the top of the Table.) Shaded cells indicate estimated values (1/2 of the reporting limit adjusted for dilution factor) and summary statistics using these estimated values.

ID	e-Waste Type	TCLP LIMIT=						
		5	100	1	5	5		
		As	Ba	Cd	Cr	Pb	Se	Ag
17	Cell	ND	ND	0.01	ND	52	ND	ND
18	Cell	NA	NA	NA	NA	NA	NA	NA
19	Cell	ND	ND	ND	ND	52	ND	ND
21	Cell	ND	ND	ND	ND	51	ND	ND
mean		ND	ND	ND	ND	52	ND	ND
cv%		ND	ND	ND	ND	14	ND	ND
UL		ND	ND	ND	ND	52	ND	ND
20	Telephone	NA	NA	NA	NA	NA	NA	NA
22	Telephone	ND	ND	ND	ND	16	ND	ND
23	Telephone	ND	ND	ND	ND	43	ND	ND
24	Telephone	ND	ND	ND	ND	75	ND	ND
mean		ND	ND	ND	ND	45	ND	ND
cv%		ND	ND	ND	ND	66	ND	ND
UL		ND	ND	ND	ND	77	ND	ND
25	Radio	ND	ND	ND	ND	20	ND	ND
26	Radio	ND	ND	0.04	ND	60	ND	ND
27	Radio	ND	ND	ND	ND	26	ND	ND
28	Radio	ND	ND	0.06	ND	110	ND	ND
mean		ND	ND	ND	ND	54	ND	ND
cv%		ND	ND	ND	ND	76	ND	ND
UL		ND	ND	ND	ND	88	ND	ND

TABLE 5. Concentrations of WET-extractable elements in mg/L of entire device. Bold face results indicate values above the respective STLC criteria (shown at the top of the Table.) Shaded cells indicate estimated values (1/2 of the reporting limit adjusted for dilution factor) and summary statistics using these estimated values.

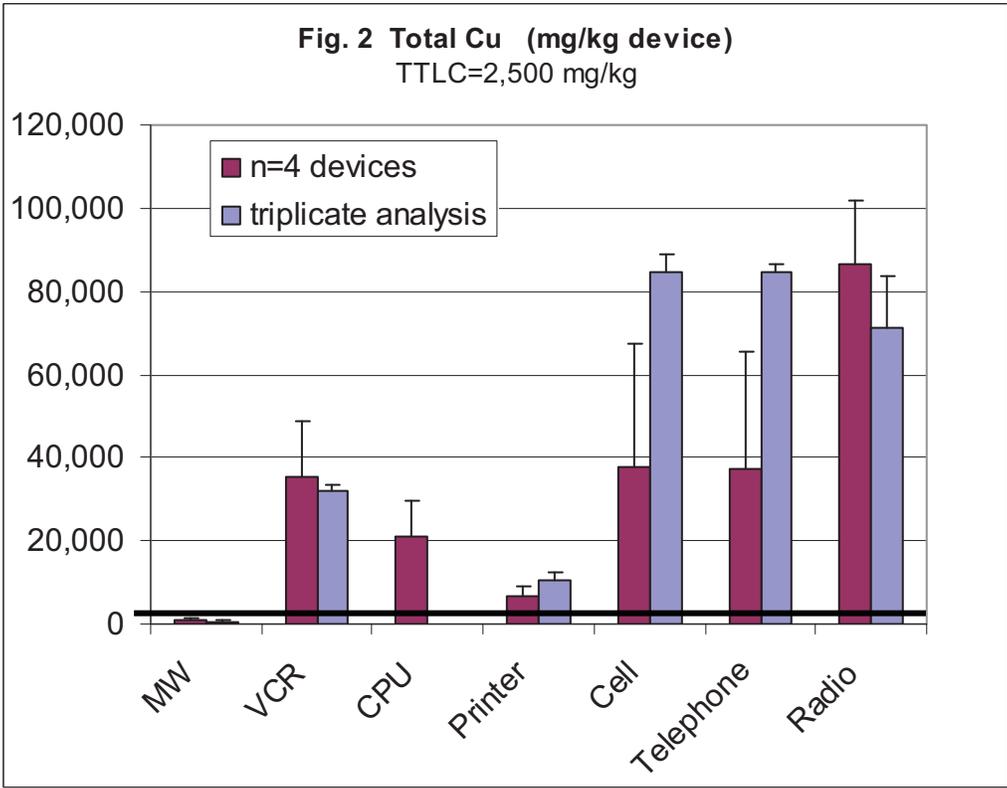
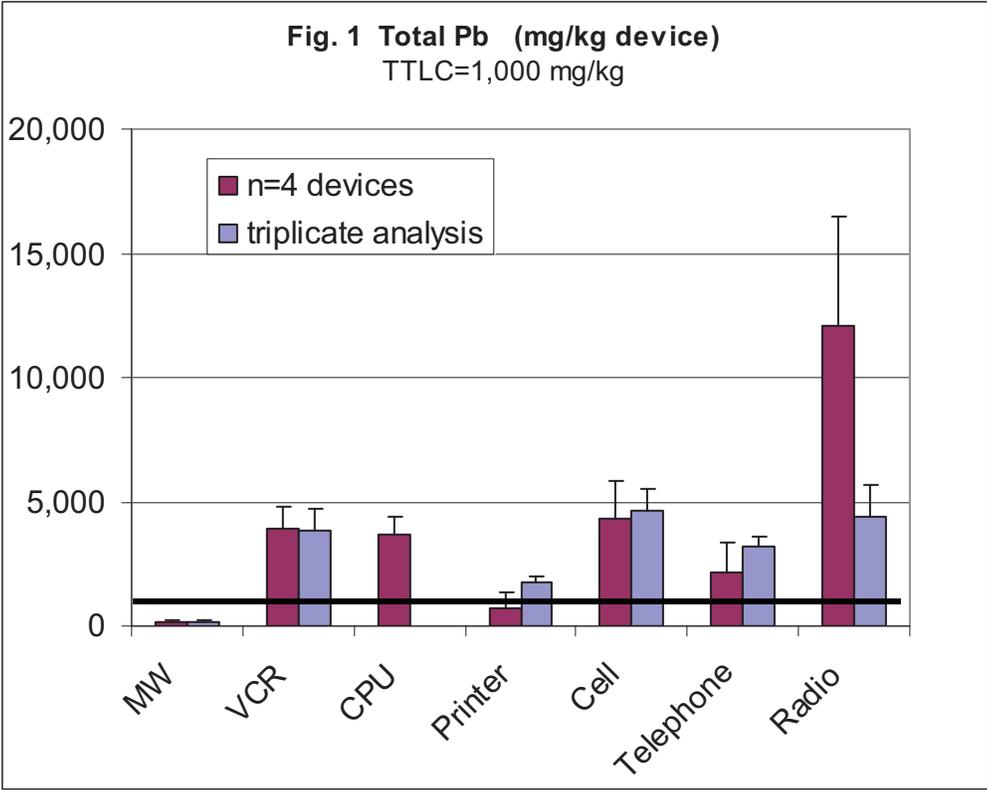
ID	e-Waste type	STLC LIMIT=										V	Zn				
		5	100	1	1	5	80	25	5	350	20			1	5	7	24
1	MW	ND	ND	ND	ND	ND	ND	0.2	8.5	ND	ND	ND	ND	ND	ND	ND	1.3
2	MW	ND	ND	ND	ND	ND	ND	0.0	4.8	ND	ND	ND	ND	ND	ND	ND	1.2
3	MW	ND	ND	ND	ND	ND	ND	0.2	13	ND	ND	ND	ND	ND	ND	ND	0.2
4	MW	ND	ND	ND	ND	ND	ND	0.2	5.1	ND	ND	ND	ND	ND	ND	ND	0.0
mean		ND	ND	ND	ND	ND	ND	0.1	7.9	ND	ND	ND	ND	ND	ND	ND	0.7
cv%		ND	ND	ND	ND	ND	ND	63	48	ND	ND	ND	ND	ND	ND	ND	96
UL		ND	ND	ND	ND	ND	ND	0.2	11	ND	ND	ND	ND	ND	ND	ND	1.2
5	VCR	ND	ND	ND	0.07	ND	ND	ND	20	ND	ND	ND	ND	ND	ND	ND	21
6	VCR	ND	ND	ND	ND	ND	ND	ND	16	ND	ND	ND	ND	ND	ND	ND	1
7	VCR	ND	ND	ND	ND	ND	ND	ND	18	ND	ND	ND	ND	ND	ND	ND	1
8	VCR	ND	ND	ND	ND	ND	ND	ND	8	ND	ND	ND	ND	ND	ND	ND	31
mean		ND	ND	ND	ND	ND	ND	ND	14	ND	ND	ND	ND	ND	ND	ND	11
cv%		ND	ND	ND	ND	ND	ND	ND	38	ND	ND	ND	ND	ND	ND	ND	156
UL		ND	ND	ND	ND	ND	ND	ND	18	ND	ND	ND	ND	ND	ND	ND	25
9	CPU	ND	1.5	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
10	CPU	ND	0.9	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	2
11	CPU	ND	2.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
12	CPU	ND	2.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
mean		ND	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
cv%		ND	36.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	36
UL		ND	2.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
13	Printer	ND	ND	ND	ND	ND	ND	0.18	97	ND	3.9	ND	ND	ND	ND	ND	1.7
14	Printer	ND	ND	ND	ND	ND	ND	3.63	51	ND	ND	ND	ND	ND	ND	ND	1.3
15	Printer	ND	ND	ND	ND	ND	ND	20.33	40	ND	ND	ND	ND	ND	ND	ND	0.9
16	Printer	ND	ND	ND	ND	ND	ND	5.25	21	ND	17.2	ND	ND	ND	ND	ND	0.4
mean		ND	ND	ND	ND	ND	ND	7.35	52	ND	ND	ND	ND	ND	ND	ND	1.1
cv%		ND	ND	ND	ND	ND	ND	121.2	62	ND	ND	ND	ND	ND	ND	ND	50
UL		ND	ND	ND	ND	ND	ND	14.64	79	ND	ND	ND	ND	ND	ND	ND	2

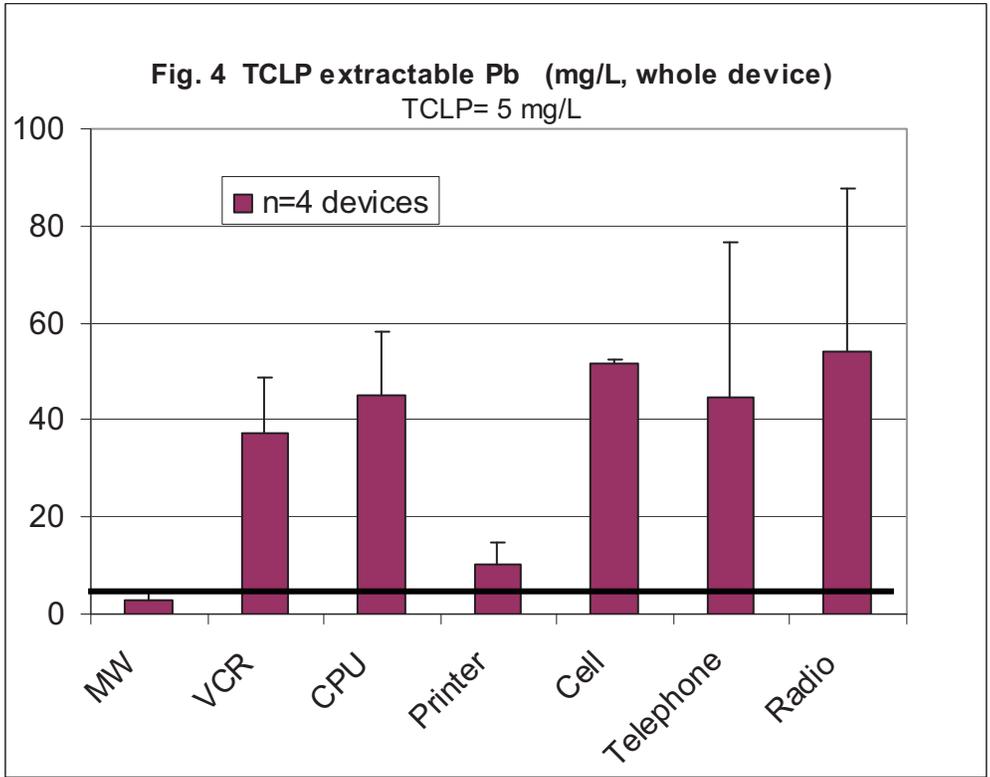
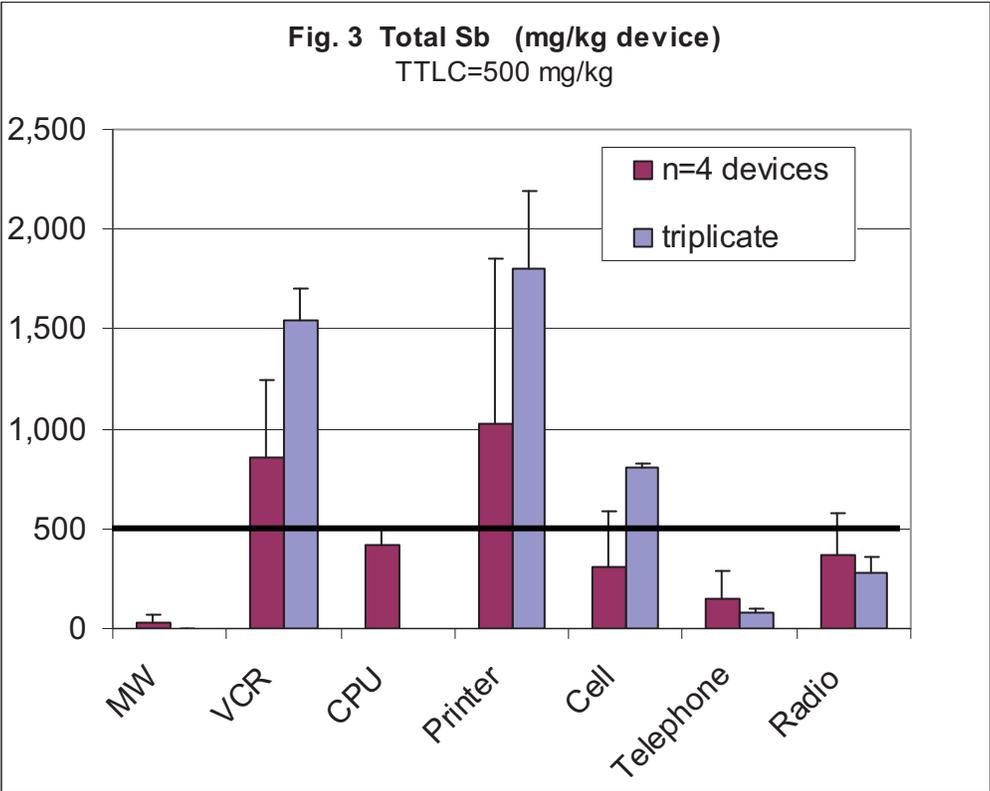
TABLE 5. Cont'd. Concentrations of WET extractable elements in mg/L of entire device. Bold face results indicate values above the respective STLC criteria (shown at the top of the Table.) Shaded cells indicate estimated values (1/2 of the reporting limit adjusted for dilution factor) and summary statistics using these estimated values.

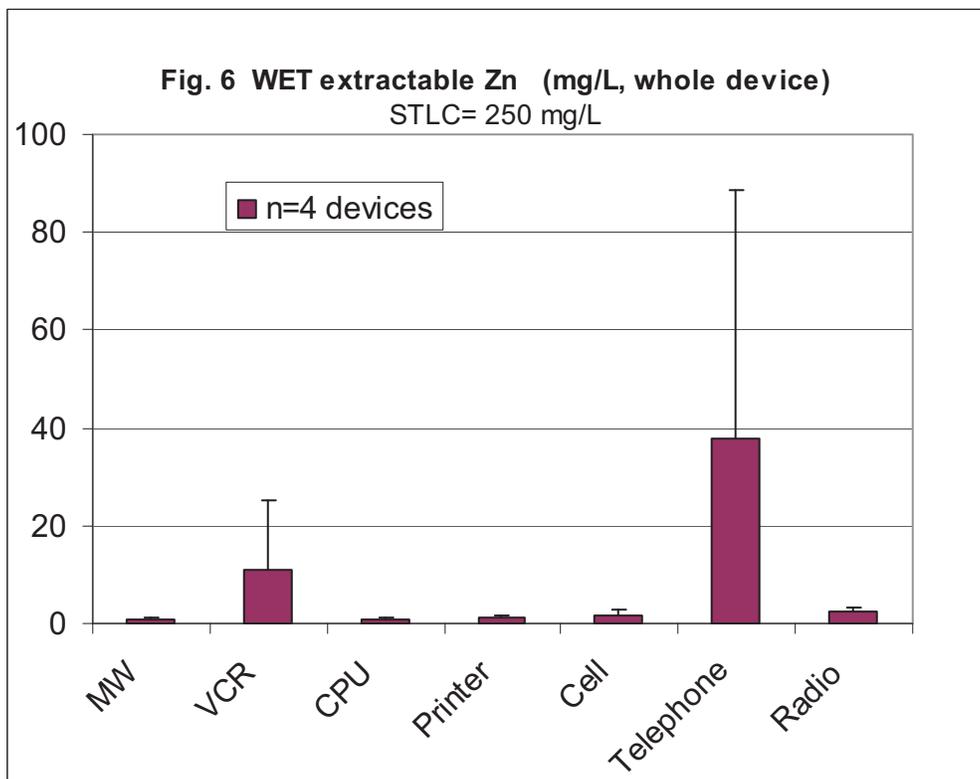
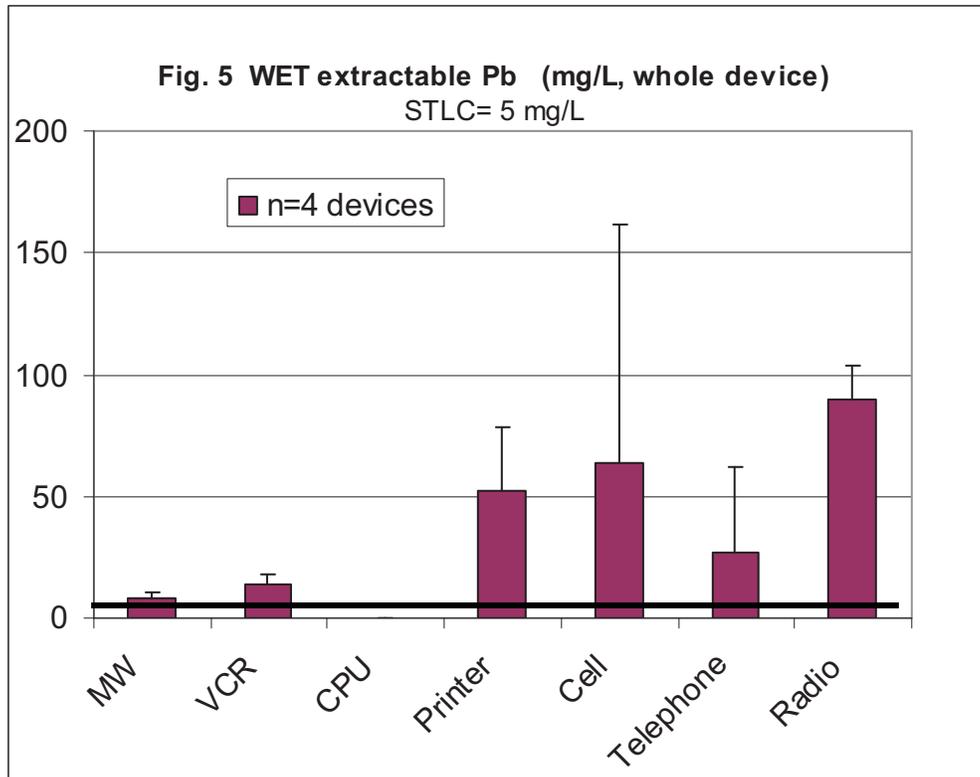
STLC LIMIT=		5	100	1	1	5	80	25	5	350	20	1	5	7	24	250
ID	e-Waste Type	As	Ba	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Ag	Tl	V	Zn
17	Cell	ND	3.46	ND	ND	ND	ND	ND	52	ND	ND	ND	ND	0.2	ND	2
18	Cell	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
19	Cell	ND	ND	ND	ND	ND	ND	ND	127	ND	ND	ND	ND	ND	ND	1
21	Cell	ND	ND	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	2
mean		ND	ND	ND	ND	ND	ND	ND	64	ND	ND	ND	ND	ND	ND	2
cv%		ND	ND	ND	ND	ND	ND	ND	141	ND	ND	ND	ND	ND	ND	76
UL		ND	ND	ND	ND	ND	ND	ND	161	ND	ND	ND	ND	ND	ND	3
20	Telephone	ND	5.61	ND	0.02	ND	ND	ND	3.4	ND	ND	ND	ND	ND	ND	5
22	Telephone	ND	ND	ND	ND	ND	ND	ND	1.9	ND	ND	ND	ND	ND	ND	3
23	Telephone	ND	ND	ND	ND	ND	ND	ND	77	ND	ND	ND	ND	ND	ND	1
24	Telephone	ND	ND	ND	ND	ND	ND	ND	1.6	ND	ND	ND	ND	ND	ND	109
mean		ND	ND	ND	ND	ND	ND	ND	27	ND	ND	ND	ND	ND	ND	38
cv%		ND	ND	ND	ND	ND	ND	ND	162	ND	ND	ND	ND	ND	ND	164
UL		ND	ND	ND	ND	ND	ND	ND	62	ND	ND	ND	ND	ND	ND	88
25	Radio	ND	ND	ND	ND	ND	ND	2.66	75	ND	ND	ND	ND	ND	ND	2
26	Radio	ND	ND	ND	0.69	ND	ND	0.25	113	ND	ND	ND	ND	ND	ND	2
27	Radio	ND	ND	ND	ND	ND	ND	0.55	93	ND	ND	ND	ND	0.4	ND	3
28	Radio	ND	ND	ND	ND	ND	ND	21	77	ND	ND	ND	ND	ND	ND	4
mean		ND	ND	ND	ND	ND	ND	6.1	89	ND	ND	ND	ND	ND	ND	2
cv%		ND	ND	ND	ND	ND	ND	163	19	ND	ND	ND	ND	ND	ND	41
UL		ND	ND	ND	ND	ND	ND	14.3	104	ND	ND	ND	ND	ND	ND	3

TABLE 6. eWaste products exceeding hazardous waste criteria. Decision is based on the 90% Upper Confidence Level. When the sample size (n=4) was inadequate to compare to the hazardous waste criterion (assuming a normal distribution), the respective element is marked by an asterisk.

Product Type	ELEMENTS EXCEEDING RESPECTIVE CRITERIA		
	TOTALS	TCLP	WET
	>TTLC	>TCLP limit	>STLC
Microwave Ovens	-	-	Pb
VCR	Sb, Cu, Pb	Pb	Pb
CPU	Sb, Cu, Pb	Pb	-
Printer	Cu, Pb*, Sb*	Pb	Pb
Cell	Sb, Cu, Pb, Cr*, Ni*	Pb	Pb
Telephone	Cu, Pb, Ni*	Pb	Pb
Radio	Cu, Pb, Sb*	Pb	Pb







Appendix A.

SOP-733S. Sample Preparation of Electronic Waste (E-waste) Samples for the Analysis of Semi-volatiles and Metals

SOP Status: Draft

Approved by:

(Chief, HML)

(HML QA/QC Officer)

(Supervisor)

**Sample Preparation of Electronic Waste (E-waste) Samples
for Analysis of Semi-volatiles and Metals**

1. Scope and Application

- 1.1 This procedure is applicable to prepare electronic waste (E-waste) samples requiring analysis for semi-volatile organics and inorganic substances. When waste characterization for regulated substances is requested, pre-preparation procedures derived from Title 22, §66261.24 (a) (1) [the TCLP] and/or 66261.24 (a) (2) [persistent and bio-accumulative toxic substances] are applied as required.
- 1.2 This procedure is used to prepare samples from various E-wastes such as; cellular phones, video cassette recorders, domestic microwave ovens, computers, printers, and telephone/answering machines, etc. The purpose behind this approach is as follows:
 - 1.2.1 Shredding and milling of E-waste samples to pass through a No. 10 (2mm) sieves designed to simulate the scenario of landfill materials being crushed/ground/weathered, to finer materials and thereby increasing their tendency to release toxic substances into the environment. Every effort must be made to reduce the particle size to pass through a 9.5 mm, 2 mm(No. 10) and 1 mm(No. 18) sieves sequentially, to meet the TCLP, WET and Total semi volatile analysis requirements. Due to the nature of E-waste matrices these particle sizes may not be achieved, and then every effort must be made to reduce the particle size close to the above requirements.
 - 1.2.2 By shredding and milling the E-waste samples to pass through a No. 10 and No. 18 sieve, the sample homogeneity increases and should result in increased precision of the analyses.
 - 1.2.3 Employing one uniform pre-preparation procedure provides a consistent and simplified approach to preparing all kinds of E-waste samples.
- 1.3 This SOP describes the procedure to prepare samples prior to any extraction or digestion procedure that may be required before subsequent analyses.

- 1.4 This procedure is recommended for use by laboratory assistants or technicians working under the close supervision of chemists experienced in the sample preparation requirements for semi-volatile organic and inorganic analyses.

2.0 Summary

- 2.1 The total weight of each type of E-waste sample submitted is weighed and recorded (waste samples of the same type can be grouped together as one sample). The E-waste samples are dismantled and components are classified as plastic, circuit board, or metal. Weight of each component, e.g., circuit board (with capacitors, transistors, battery), plastic and metal should be recorded and stored in separate containers before particle size reduction.
- 2.2 Each component of E-waste sample is representatively sampled, shredded, milled to pass through a No. 10 (or No.5) sieve, mixed for homogeneity, and then sampled for the requisite extraction or digestion procedures.
- 2.3 Particle size reduction is achieved by milling and grinding to the required mesh size. An appropriate shredder and mill or grinder is used for this process.
- 2.4 Interferences from carry over from one waste to another must be minimized by cleaning the equipment with dry wood chips and pressurized air. All containers must be clean and free of organic and inorganic substances. Small milling or grinding units may be cleaned as described in HML SOP 704-S.

3.0 Safety

- 3.1 Sample preparation should be performed in a well ventilated high ceiling room.
- 3.2 Nitrile gloves may be worn for hand protection, but must not come in contact with the sample, or the interior of the sample containers, to avoid contamination.
- 3.3 Use safety glasses or goggles when shredding and milling or grinding the samples.
- 3.4 The operator must wear a dust mask and coveralls if necessary during the process.
- 3.5 The working area (counters, equipment, tools, etc.) should be kept clean at all times.
- 3.6 Operating instructions must be followed while using the shredder and/or grinder.

4.0 Apparatus and Materials

- 4.1 Hand tools for dismantling e.g. special screw drivers for electronic products, electric drill/saw, cutters and pliers, etc.

- 4.2 Sieve No. 10 mesh (2 mm), Sieve No. 18 (1 mm) and 9.5 mm mesh size.
- 4.3 Rotary mill or an automatic grinder capable of grinding small pieces of plastic and printed circuit boards.
- 4.4 Electric cutter or a shredding machine capable of reducing the particle size of the plastic material into small pieces.
- 4.5 Top loading balance 20 Kg capacity (accurate to +/-1.0 g).
- 4.6 Top loading balance 1 Kg capacity (accurate to +/- 0.2 g).
- 4.7 Dust masks, face shields or eye goggles.
- 4.8 Nitrile gloves.
- 4.9 Teflon or glass containers of appropriate size for storing the prepared samples.
- 4.10 Liquid nitrogen
- 4.11 Deionized water
- 4.12 Nitric acid, 5 percent
- 4.13 Acetone

5.0 Procedure

- 5.1 Weigh each E-waste or a group of a kind of E-waste sample and record. Dismantle and separate into its major components, namely plastic and printed circuit boards. Remove extraneous material like casing, nuts, screws, loose wires, metal brackets and large capacitors.
 - 5.1.1 Plastic and circuit board components:
Separate plastic and circuit board components (with all the electronic components intact on the circuit board) from each type of E-waste. Record tare and sample component weights and store separately in properly identified glass or Teflon containers.
 - 5.1.2 Metal components of the E-waste sample is weighed and stored in a separate container labeled as scrap metal for recycling. No particle size reduction on this portion of the sample.
- 5.2 Each component (plastic and circuit boards) is passed through the cutter/ shredder to break down into small pieces. After this preliminary preparation step, the sample is

ground in a mill or grinder to a fine particle size.

- 5.3 Clean the equipments after processing each component. Pass dried wood chips through the shredder/cutter and mill/grinder. Inspect equipments for left over wood chips, then blast through the equipments with pressurized air to ensure they are completely free of sample particles or wood chips. **Wear masks and goggles.**
- 5.4 The entire sample is sieved through the 9.5 mm, 2 mm, and 1 mm sieves sequentially to meet the TCLP, WET and Total semivolatile analysis. Record the weight of each fraction and store in a glass container properly labeled at 4⁰ C.
- 5.5 Repeat the cleaning process as in step 5.3 after all the samples have been processed.

6 **Alternative Procedure For E-waste Sample Preparation:**

In case the above procedure is not possible to reduce the particle size of the samples, the following alternative approach may be applied.

- 6.1 Weigh and record the total weight of each sample or a like kind group of E-waste samples. Dismantle each sample and separate into its major components like plastic, printed circuit board and scrap metal containing metal casing, nut, screws, large capacitors, metal brackets and wires. Record all the weights separately and store in separate glass or Teflon containers properly labeled.
 - 6.1.1 Metal part of the E-waste samples is weighed and stored in a labeled plastic container. This part of the waste is for recycling only; no particle size reduction will be performed.
- 6.2 Only printed circuit boards (with all the electronic components intact) and plastic part of the sample were cut into smaller pieces by using all mechanical means like the electric drill and/or diamond saw, cutters, pliers and hammers. Sometimes plastic is hard to cut but breaking with hammer and a cutter may work out.
- 6.3 Small cut pieces of each waste sample were collected at random from the pile of broken pieces and were frozen separately in liquid nitrogen for 2 hours to facilitate further breaking and crushing.
- 6.4 The frozen pieces were crushed into smaller size by using the cutters, hammers, pestle mortar and a hydraulic press if necessary to achieve the finer particle size that should pass through 9.5 mm sieve. **Record the final weight of the sample prepared by this procedure and store in a glass or Teflon container at 4⁰C.**
- 6.5 Clean all the equipment by rinsing with DI water, 5 percent nitric acid, DI water and acetone in series and air dry before using for the next sample.
- 6.6 Sieved portions of the sample should be used to perform the organic and inorganic

analysis.

7 Quality Control

Although most of these QC requirements are defined in analytical procedures, some additional requirements have been introduced to check the efficiency, precision and accuracy of all the procedures. **A sample batch is defined as a group of 10 samples or fewer, that is processed together and is comprised of samples of similar matrix.**

- 7.1 With a batch of each matrix type (plastic and circuit boards) of E-waste, one method blank should be included, containing all the reagents and processed with the sample batch.
- 7.2 In a batch of each matrix type of E-waste, one sample must be prepared in sufficient quantity by using one of the above particle size reduction methods. Divide this sample into three portions.
- 7.3 One portion of the sample (7.2) should be analyzed as unspiked to check the background contamination (plastic or circuit board). The other two portions should be used for matrix spike and matrix spike duplicate.
- 7.4 A method standard is run containing all the elements/compounds of interest with each batch of samples. Standards from the same vendor must be used as that used for matrix spike and matrix spike duplicate. Spiking standards must be acquired from the vendor other than the calibrating standards.
- 7.5 In a batch, one sample (different than one used for MS, MSD) should be run in triplicate for each matrix the precision and homogeneity of the sample preparation method. **(Additional QC).**

8.0 References

- 8.1 Title 22. California Code of Regulations, Article 3. §66261
- 8.2 HML - SOP 704S: Operation and cleaning of automated milling equipment.

9.0 Acknowledgement

This SOP was developed and written by the staff of Hazardous Materials Laboratory, California Department of Toxic Substances Control. For more information please call Jarnail Garcha at (510) 540-3468.

Appendix - B

Table QC-1 Quality Control and MS & MSD Results for Total Metals

Sample Number	E-waste Type	Batch #	Spike Level (mg/L)	Sb	As	Ba	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Ag	Tl	V	Zn
Blank		3G18008 BLK5		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LCS		3G18008BS 1	50.0	50.6	48.4	49.1	52.0	48.2	49.7	49.8	49.2	49.2	49.4	51.0	47.2	47.8	48.1	50	49.0
% Rec				101	96.8	98.2	104	96.4	99.4	99.6	98.4	98.4	98.8	102	94.4	95.6	96.2	100	98
5	VCR			2900	ND	940	20	4.8	9.1	7.6	81000	12000	2.9	240	ND	230	ND	ND	5300
MS		3G18008 MS1	50.0	3930	38.8	1510	51.8	50.7	56.0	55.8	120000	9460	34.4	330	36.1	88.8	36.5	ND	7790
MSD		3G18008 MSD1	50.0	3440	39.3	323	53.0	48.9	138	53.8	83800	8460	37.5	424	33.5	165	42.9	ND	3020
%Rec MS		3G18008		NR	77.6	NR	63.6	91.8	93.8	96.4	NR	NR	63.0	180	72.2	NR	73		NR
				QM-4X		QM-4X	QM-07				QM-4X	QM-4X	QM-07	QM-4X	QM-07	QM-07	QM-07	QM-07	QM-07
%Rec MSD		3G18008		NR	79.6	NR	66	88.2	258	92.4	NR	NR	69.2	368	67	NR	85.8		NR
				QM-4X		QM-4X	QM-07		QM-07		QM-4X	QM-4X	QM-07	QM-4X	QM-07	QM-07		QM-07	QM-4X
RPD				13.3	1.28	130	2.29	3.61	84.5	3.65	35.5	11.2	8.62	24.9	7.47	60.0	16.1		88.3
Blank		3H06021 BLK1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LCS		3H06021 BS1	50.0	48.4	42.0	44.0	46.3 ¹	44.6	45.5	45.6	46.9	47.2	44.3	45.7	45.0	44.6	43.7	45.2	45.6
% Rec				96.8	84.0	88.0	92.6	89.2	91.0	91.2	93.8	94.4	88.6	91.4	90.0	89.2	87.4	90.4	91.2
19	Cell Phone			1200	5.2	1600	230	1.7	30	78	120000	5200	13	2000	ND	220	ND	ND	2600
MS		3H06021 MS1	50.0	1300	33.3	1950	620	44.7	85.1	166	138000	3570	17.1	1790	39.8	123	35.7	ND	ND
MSD		3H06021 MSD1	50.0	944	18.5	791	47.0	43.5	64.7	544	95400	2540	5.45	776	32.7	124	35.1	ND	ND
%Rec MS				200	56.2	700	780	86.0	110	176	NR	NR	8.20	NR	79.6	NR	71.4		NR
				QM-4X	QM-07	QM-07	QM-06				QM-4X	QM-4X	QM-07	QM-4X	QM-07	QM-07	QM-07	QM-07	QM-07
%Rec MSD				NR	26.6	NR	NR	83.6	69.4	932	NR	NR	NR	NR	65.4	NR	70.4		NR
				QM-4X	QM-07	QM-4X	QM-06		QM-07	QM-4X	QM-4X	QM-4X	QM-07	QM-4X	QM-07	QM-07	QM-07	QM-07	QM-07
RPD				31.7	57.1	84.6	172	2.72	27.2	106	36.5	33.7	103	79.0	19.6	0.810	1.69		

ND = Analyte NOT DETECTED at or above the reporting limit
 QM-06 Due to noted non-homogeneity of the QC sample matrix, the MS/MSDs did not provide reliable results for accuracy and precision.
 Sample results for the QC batch were accepted based on LCS/LCSD percent recoveries and RPD values.
 QM-07 The spike recovery was outside control limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.
 QM-4x The spike recovery was outside of control limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration.
 The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.

Table QC-1 (cont.). Quality Control and MS & MSD Results for Total Metals

Sample Number	E-waste Type	Batch #	Spike Level (mg/L)	Sb	As	Ba	Be	Cd	Cr	Co	Cu	Pb	Mo	Ni	Se	Ag	Tl	V	Zn
Blank		3G16031 BLK1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LCS		3G16031 BS1	50.0	50.2	47.6	50.2	50.8	47.5	50.3	50.2	49.9	49.0	48.1	49.5	45.9	49.0	49.8	50.7	48.5
% Rec				100	95.2	100	102	95	101	100	99.8	98	96.2	99	91.8	98	99.6	101	97
20	Cell phone			160	6.2	2400	10	ND	2500	170	120000	4300	27	3000	ND	140	ND	ND	3600
MS		3G16031 MS1	50.0	123	47.1	1460	47.5	41.6	2640	192	95200	3130	76.1	2310	35.4	122	41.3	ND	1600
MSD		3G16031 MSD1	50.0	122	56.1	5480	314	45.4	1490	239	132000	5430	58.5	4660	43.2	164	13.2	ND	2230
%Rec MS				NR	81.8	NR	75	83.2	280	44	NR	NR	98.2	NR	70.8	NR	82.6	ND	NR
%Rec MSD				NR	99.8	NR	608	90.8	NR	138	NR	NR	63	NR	86.4	48	26.4	ND	NR
RPD				0.816	17.4	116	147	8.74	55.7	21.8	32.4	53.7	26.2	67.4	19.8	29.4	103	ND	32.9
Blank		3G16030 BLK1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LCS		3G16030 BS1	50.0	49.9	46.8	48.2	51.4	48.1	49.9	50.4	47.4	49.4	48.5	50.9	46.1	48.3	47.5	50.4	49.4
% Rec				99.8	93.6	96.4	103	96.2	99.8	101	94.8	98.8	97.0	102	92.2	96.6	95.0	101	98.8
28	Radio			87	ND	110	ND	7.1	ND	1.6	46000	1500	ND	74	ND	12	ND	ND	280
MS		3G16030 MS1		356	45.1	506	51.6	50.8	53.0	56.3	64300	5060	45.4	649	44.3	122	42.1	ND	5270
MSD		3G16030 MSD1		303	40.4	448	49.0	53.2	49.6	48.8	53000	3640	38.6	245	41.9	68.4	41.3	ND	9130
%Rec MS				538	90.2	792	103	87.4	106	109	NR	NR	90.8	NR	88.6	220	84.2	ND	NR
%Rec MSD				QM-4X		QM-4X					QM-4X	QM-4X		QM-4X		QM-07		QM-FX	QM-4X
RPD				432	80.8	676	98.0	92.2	99.2	94.4	NR	NR	77.2	342	83.8	113	82.6	ND	NR
				QM-4X		QM-4X					QM-4X	QM-4X		QM-4X		QM-07		QM-FX	QM-4X
				16.1	11.0	12.2	5.17	4.62	6.63	14.3	19.3	32.6	16.2	90.4	5.57	56.3	1.92	ND	53.6

ND = Analyte NOT DETECTED at or above the reporting limit
 QM-06 Due to noted non-homogeneity of the QC sample matrix, the MS/MSDs did not provide reliable results for accuracy and precision. Sample results for the QC batch were accepted based on LCS/LCSD percent recoveries and RPD values.
 QM-07 The spike recovery was outside control limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.
 QM-4x The spike recovery was outside of control limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration. The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.

Table QC-II Quality Control and MS & MSD Results for WET-extractable elements

Sample Number	E-waste Type	Batch #	Spike Level (mg/L)	Al	As	Ba	Be	Cd	Cr	Cu	Co	Pb	Mo	Ni	Ag	Se	Tl	V	Zn
Blank		3H07013 BLK1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LCS		3H07013-BS1	2.00	1.94	2.06	1.90	1.88	1.89	1.92	1.89	1.93	2.00	1.93	1.95	1.92	1.80	1.94	1.92	1.94
% Rec				97.0	103	95	94	94.5	96	94.5	96.5	100	96.5	97.5	96	90	97	96	97
7	VCR			1.5	0.23	0.31	ND	ND	ND	ND	0.35	50	ND	2.9	ND	ND	0.39	ND	3.7
MS		3H07013-MS1	2.00	11.8	2.05	11.1	1.93	1.94	1.98	1.94	1.99	0.994	1.96	1.99	1.93	1.81	1.93	1.97	1.99
MSD		3H07013-MS1	2.00	11.8	2.11	11.1	1.94	1.95	1.98	1.95	1.99	1.01	2.00	2.00	1.94	1.82	1.96	1.98	2.00
%Rec MS				515	91.0	540	96.5	97	99	97	82.0	NR	98.0	NR	96.5	90.5	77	98.5	NR
%Rec MSD				QM-07		QM-07					QM-07			QM-07			QM-07		QM-07
				515	94.0	540	97.0	97.5	99.0	97.5	82.0	NR	100	NR	97.0	91.0	78.5	99	NR
				QM-07		QM-07					QM-07			QM-07			QM-07		QM-07
RPD				0.00	2.88	00.00	0.517	0.514	0.00	0.514	0.00	1.60	2.02	0.501	0.517	0.551	1.54	0.506	0.501
Blank		3G29009BLK1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LCS		3G29009 BS1	2.00	2.02	1.89	1.97	1.94	1.99	1.98	1.93	2.00	1.95	1.99	2.02	1.96	1.80	2.03	1.98	2.01
% Rec				101	94.5	98.5	97.0	99.5	99.0	96.5	100	97.5	99.5	101	98.0	90.0	102	99.0	100
10	CPU			1.8	ND	2.9	ND	0.049	ND	ND	0.40	6.8	ND	1.6	ND	ND	ND	ND	6.7
MS		3G29009-MS1	2.00	3.73	1.91	4.74	1.94	2.04	2.03	1.97	2.40	9.12	2.00	3.57	1.89	1.79	2.07	1.99	8.55
MSD		3G29009-MSD1	2.00	3.76	2.00	4.72	1.94	2.05	2.05	1.96	2.39	8.56	2.00	3.58	1.89	1.83	2.15	1.99	8.56
%Rec MS				96.5	95.5	92.0	97.0	99.6	102	98.5	100	116	100	98.5	94.5	89.5	104	99.5	92.5
%Rec MSD				98.0	100	91.0	97.0	100	102	98.0	99.5	88.0	100	99.0	94.5	91.5	108	99.5	93.0
RPD				0.801	4.60	0.423	0.00	0.489	0.980	0.509	0.418	6.33	0.00	0.280	0.00	2.21	3.79	0.00	0.117

ND = Analyte NOT DETECTED at or above the reporting limit
 QM-06 Due to noted non-homogeneity of the QC sample matrix, the MS/MSDs did not provide reliable results for accuracy and precision.
 Sample results for the QC batch were accepted based on LCS/LCSD percent recoveries and RPD values.
 QM-07 The spike recovery was outside control limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.
 QM-4x The spike recovery was outside of control limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration.
 The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.

Table QC-II (cont). Quality Control and MS & MSD Results for WET-extractable elements

Sample Number	E-waste Type	Batch #	Spike Level (mg/L)	Al	As	Ba	Be	Cd	Cr	Cu	Co	Pb	Mo	Ni	Ag	Se	Tl	V	Zn
Blank		3G19001-BLK1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LCS		3G19001-BS1	2.00	1.97	2.27	1.93	1.96	2.00	1.99	1.92	2.00	1.96	1.99	2.02	1.95	1.77	2.11	1.98	2.02
% Rec				98.5	114	96.5	98.0	100	99.5	96.0	100	98.0	99.5	101	97.5	88.5	106	99.0	101
20	Cell Phone			2.00	ND	10	ND	0.028	ND	ND	4.2	6.1	ND	1.3	ND	ND	0.45	ND	9.8
MS		3G19001-MS1	2.00	3.84	2.36	11.9	2.03	2.06	2.27	1.87	6.54	8.66	2.05	3.44	1.86	1.95	2.46	2.07	12.5
MSD		3G19001-MSD1	2.00	3.85	2.22	11.9	2.00	2.04	2.25	1.85	6.51	8.37	2.06	3.45	1.83	1.85	2.45	2.06	12.4
%Rec MS				92.0	118	95.0	102	102	114	93.5	117	128	102	107	93.0	97.5	100	104	135
								QM-07			QM-07	QM-07							QM-07
%Rec MSD				92.5	111	95.0	100	101	112	92.5	116	114	103	108	91.5	92.5	100	103	130
											QM-07	QM-07							QM-07
RPD				0.260	6.11	0.00	1.49	0.976	0.885	1.08	0.460	3.41	0.487	0.290	1.63	5.26	0.407	0.484	0.803
Blank		3H27033-BLK1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LCS		3H27033-BS1	2.00	1.95	1.86	1.91	1.92	1.97	1.98	1.95	1.97	1.94	1.95	2.13	1.93	2.01	1.99	1.94	2.01
% Rec				97.5	93.0	93.5	96.0	98.5	99.0	97.5	98.5	97.0	97.5	106	96.5	100	99.5	97.0	100
1	Microwave Oven			0.23	ND	0.15	ND	ND	ND	1.8	ND	67	ND	3.7	ND	0.02	ND	ND	10.0
MS		3H27033	2.00	2.18	1.91	2.06	1.90	1.93	1.95	3.86	1.97	73.5	1.91	5.88	1.90	1.91	1.98	1.97	12.7
MSD		3H27033	2.00	2.20	2.02	2.07	1.92	1.95	1.98	3.86	2.00	73.7	1.94	5.91	1.93	1.94	1.92	1.98	12.7
%Rec MS				97.5	95.5	95.5	95.0	96.5	97.5	103	98.5	325	95.5	109	95.0	94.6	99.0	98.5	135
											QM-4X	QM-4X							QM-4X
%Rec MSD				98.5	101	96.0	96.0	97.5	99.0	103	100	335	97.0	110	96.5	96.0	96.0	99.0	135
											QM-4X	QM-4X							QM-4X
RPD				0.913	5.60	0.484	1.05	1.03	1.53	0.00	1.51	0.272	1.56	0.509	1.57	1.56	3.08	0.506	0.00

ND = Analyte NOT DETECTED at or above the reporting limit
 QM-06 Due to noted non-homogeneity of the QC sample matrix, the MS/MSDs did not provide reliable results for accuracy and precision.
 Sample results for the QC batch were accepted based on LCS/LCSD percent recoveries and RPD values.
 QM-07 The spike recovery was outside control limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.
 QM-4X The spike recovery was outside of control limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration.
 The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.

Table QC-II (cont.). Quality Control and MS & MSD Results for WET-extractable elements

Sample Number	E-waste Type	Batch #	Spike Level (mg/L)	Al	As	Ba	Be	Cd	Cr	Cu	Co	Pb	Mo	Ni	Ag	Se	Tl	V	Zn
Blank		3J08004 BLK1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LCS		3J08004	2.00	2.00	1.96	1.96	1.99	1.99	1.99	1.96	1.99	1.97	1.97	2.01	1.96	2.00	1.96	1.98	2.01
% Rec				100	100	98.0	98.0	99.5	99.5	98.0	99.5	98.5	98.5	100	98.0	100	98.0	99.0	100
8	VCR	3J08004		2.00	ND	0.24	ND	0.016	ND	0.16	ND	24	ND	2.3	ND	ND	ND	ND	94
MS		3J08004	2.00	4.04	1.95	2.23	1.95	2.01	2.05	2.14	2.13	22.6	2.03	4.36	1.89	1.76	2.05	1.99	97.4
MSD		3J08004	2.00	3.96	2.15	2.22	1.98	2.00	2.06	2.15	2.14	25.7	2.02	4.33	1.88	1.94	2.08	2.01	95.5
%Rec-MS				102	97.5	99.5	97.5	99.7	102	99.0	106	-70	102	103	94.5	88.0	102	99.5	170
%Rec MSD				98.0	108	99.0	99.0	99.2	103	99.5	107	85.0	101	102	94.0	97.0	104	100	75
RPD				2.00	9.76	0.449	1.53	0.499	0.487	0.466	0.468	12.8	0.494	0.690	0.531	9.73	1.45	1.00	1.97

ND = Analyte NOT DETECTED at or above the reporting limit
 QM-06 Due to noted non-homogeneity of the QC sample matrix, the MS/MSDs did not provide reliable results for accuracy and precision.
 Sample results for the QC batch were accepted based on LCS/LCSD percent recoveries and RPD values.
 QM-07 The spike recovery was outside control limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.
 QM-4x The spike recovery was outside of control limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration.
 The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.

Table III-Quality Control and MS & MSD Results for TCLP-extractable elements

Collector's Sample #:	E-waste Type	Batch No.	Spike Level (mg/L)	As	Ba	Cd	Cr	Pb	Se	Ag
Blank		3G28019		ND	ND	ND	ND	ND	ND	ND
LCS		3G28019-BS1	0.800	0.752	1.55	0.701	0.780	0.714	0.753	0.714
% Rec				94	194 ¹	87.6	97.5	89.2	94.1	89.2
Blank		3I03033-BLK1		ND	ND	ND	ND	ND	ND	ND
LCS		3I03033-BS1	0.800	0.801	0.740	0.785	0.768	0.770	0.749	0.759
% Rec				100	92.5	98.1	96.0	96.2	93.6	94.9
1	Microwave Oven			ND	0.058	ND	ND	13	ND	ND
MS		3I03033-MS1	0.800	0.790	0.796	0.788	0.770	13.4 ³	0.681	0.762
MSD		3I03033-MSD1	0.800	0.811	0.785	0.768	0.755	13.0 ³	0.741	0.744
%Rec MS				98.8	92.2	98.5	96.2	50	85.1	95.2
% Rec MSD				101	90.9	96.0	94.4	0.00 ³	92.6	93.0
RPD				2.62	1.39	2.57	1.97	3.03	8.44	2.39
Blank		3J10010-BLK1		ND	ND	ND	ND	ND	ND	ND
LCS		3J10010 BS1	0.800	0.892	1.44	0.848	0.849	0.860	0.884	0.796
% Rec				112	180 ¹	106	106	108	110	99.5
8	VCR	3J10010		ND	0.73	0.0081	ND	100	ND	ND
MS		3J10010-MS1	0.800	0.941	1.56	0.815	0.842	112	0.901	0.665
MSD		3J10010-MSD1	0.800	0.833	1.48	0.790	0.797	103	0.824	0.759
%Rec MS				118 ¹	104	101	105	NR ³	113	83.1
% Rec MSD				104	93.8	97.7	99.6	375 ³	103	94.9
RPD				12.2	5.26	3.12	5.49	8.37	8.93	13.2
Blank		3H07021-BLK1		ND	ND	ND	ND	ND	ND	ND
LCS		3H07021-BS1	0.800	0.752	0.778	0.805	0.788	0.790	0.702	0.772
% Rec				94.0	97.2	101	98.5	98.8	87.8	96.5
7	VCR			ND	0.17	ND	ND	110	ND	ND
MS		3H07021-MS1	0.800	0.811	0.956	0.816	0.819	114	0.714	0.783
MSD		3H07021-MSD1	0.800	0.837	0.958	0.820	0.826	114	0.756	0.785
%Rec MS				101	98.2	102	102	500 ³	89.2	97.9
% Rec MSD				105	98.5	102	103	500 ³	94.5	98.1
RPD				3.16	0.209	0.489	0.851	0.00	5.71	0.255

¹ = Q-LIM The percent recovery was outside of the control limits. The sample results may still be useful for their intended purpose.

² = QM-07 The spike recovery was outside control limits for the MS and/or MSD. The batch was accepted based on acceptable LCS recovery.

³ = QM-4x The spike recovery was outside of control limits for the MS and/or MSD due to analyte concentration at 4 times or greater the spike concentration. The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.

ND Analyte NOT DETECTED at or above the reporting limit.

Appendix C



Sample Dismantling Tools



Sample Milling Device



Sample separated into plastic & millable parts.



Sample collection in a stainless steel container during milling process.



Grounded Sample transferred into glass containers & ready for analysis



Cleaning of milling device after each operation.