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1 **A high-resolution ICP-MS method for the determination of 38 inorganic elements in human**
2 **whole blood, urine, hair and tissues after microwave digestion**

3

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26

27 **ABSTRACT**

28

29 Inductively coupled plasma-mass spectrometry (ICP-MS) is currently the reference method for the
30 determination of inorganic elements, and has many applications in healthcare and the environmental
31 field. The objective of the present study was to develop and validate a high-resolution ICP-MS
32 method for the simultaneous quantification of 38 elements in samples of human whole blood, urine,
33 hair and tissues after microwave mineralization. The samples were incubated with nitric acid,
34 hydrogen peroxide and internal standards prior to microwave mineralization for 25 minutes. The
35 analysis was performed with an Element XR ICP-MS and validated using commercial reference
36 standards (whole blood, urine, and hair) and in-house quality control samples. The 38 elements
37 were detected in low-, medium- or high-resolution mode, depending on interferences and
38 sensitivity. The lower and upper limits of quantification were adjusted for each element. The
39 method was linear for all elements (correlation coefficient >0.996), and the inter- and intraday
40 precision values (coefficient of variation) were below 15%. Samples from a clinical trial were used
41 to confirm the high-resolution ICP-MS method's suitability for the assessment of patient samples.

42

43 **Keywords:** Inductively coupled plasma-sector field mass spectrometry; human blood; human hair;
44 human urine, human tissue; microwave digestion; elements

45

46 **1. INTRODUCTION**

47 Inductively coupled plasma mass spectrometry (ICP-MS) is used widely to analyze trace and ultra-
48 trace elements in biological matrices. Human exposure to elements released from toxics, drugs and
49 implanted medical devices is conventionally monitored by assaying serum, blood, and urine.
50 However, tissue or hair samples often provide additional useful information. For instance, toxic
51 elements can enter the lungs through the inhalation of smoke or contaminated air. Furthermore,
52 elements absorbed by the digestive and/or pulmonary tract can find their way into the bloodstream
53 and become distributed throughout and incorporated into the body's various tissues - including the
54 hair. Hence, measurements in hair can reflect the body's cumulative exposure to the various
55 elements. Lastly, some elements may be deposited directly on the hair by external contamination [1-
56 4].

57 The limits of detection (LOD) associated with conventional quadrupole ICP-MS mean that the
58 technique is not ideal for the simultaneous quantification of several trace elements in human blood
59 or serum samples [5]. Inductively coupled plasma - sector field mass spectrometry (ICP-SFMS) has
60 greater sensitivity and resolving power; this produces LOD in the pM range [6] and enables useful
61 performance over a broad concentration range. The use of ICP-MS to assay trace elements in
62 human samples (with or without prior mineralization) has already been reported. For example, ICP-
63 MS with an octopole-based collision/reaction cell has been used to quantify 37 trace elements in
64 human blood [7]. After acid sample dilution, high-resolution ICP-MS has been applied to the
65 determination of 20 to 42 elements in human urine and serum; the concentrations were similar to
66 those observed in non-occupationally exposed populations [6, 8]. Methods for the ICP-SFMS
67 quantification of 4 to 8 abundant elements in human blood and/or serum after microwave digestion
68 have also been reported [9, 10]. Microwave digestion was shown to enhance the recovery of
69 elements and to be more reproducible and accurate than wet or dry digestion procedures [11, 12].
70 However, all the methods reported to date have various shortcomings: (i) they can only detect a

71 small number of elements simultaneously; (ii) for some elements, the LOD is above the
72 concentration found in clinical samples; (iii) analyses are restricted to blood and serum samples (i.e.
73 hair and other human tissues could not be assessed); and (iv) microwave digestion is not applied.
74 The objective of the present study was to develop and validate a method for the simultaneous
75 quantitation of 38 trace elements in human tissues, urine and whole blood samples, following
76 microwave mineralization. The method's suitability for the analysis of clinical samples was also
77 demonstrated.

78

79 **2. MATERIALS AND METHODS**

80 **2.1. Chemicals and reagents**

81 Analytical and internal standards were purchased from LGC Standards (Molsheim, France). ICP-
82 MS-grade nitric acid, hydrochloric acid, hydrogen peroxide and Triton X100 were obtained from
83 Fisher Scientific (Illkirch, France). Whole blood, urine and hair quality control (QC) samples were
84 supplied by Centre de Toxicologie du Québec (Québec, Canada). Ultrapure deionized water
85 (18m Ω) was obtained from a water station (Purelab Flex, Elga Labwater, Antony, France). Argon
86 5.0 was purchased from Messer (Puteaux, France).

87

88 **2.2. Working and calibration standard solutions**

89 Working and calibration standard solutions were prepared by diluting 1000 $\mu\text{g}\cdot\text{mL}^{-1}$ or (for Cu, Fe,
90 Rb, and Zn) 10000 $\mu\text{g}\cdot\text{mL}^{-1}$ single-element standard solutions. Three sets of 15 calibration standards
91 were prepared: the first set contained all the elements (except those detailed thereafter) in 5% HNO_3
92 in metal-free plastic tubes, the second contained Sb, Hf, Au, Pt, and Ru in 20% HCl in metal-free
93 plastic tubes, and the third contained Hg only in borosilicate tubes. The chosen standard
94 concentrations were based on those published previously for human samples. Hence, the calibration
95 range differed from one element to another: Gouille *et al.* and Cesbron *et al.* reported elemental

96 concentrations in whole blood, plasma, urine and hair samples from a population of healthy
97 volunteers in France [3, 13]; Heitland and Koster reported on the concentrations of 37 trace
98 elements in blood samples from inhabitants of northern Germany [7]; Schultze *et al.* described
99 whole blood and serum concentrations of metals in a Swedish population-based sample [14];
100 Alimonti *et al.* and Minoia *et al.* reported concentrations of metals in blood, serum or urine samples
101 from healthy adults living in Rome [15] or Lombardy [16]. To prepare the calibration curve, 10 μL
102 of each calibration standard solution were added to 190 μL of deionized water. Quality control
103 samples were stored at -20°C , whereas calibration standard stock and working solutions were stored
104 at room temperature.

105

106 **2.3. Sample preparation**

107 Whole blood, urine and tissue samples were processed directly, whereas hair samples were washed
108 first to eliminate any external contamination (using the method developed by the International
109 Atomic Energy Agency, with some modifications [17-19]). The strand of hairs was washed once
110 with 0.1% Triton X100, three times with deionized water and then once with acetone, prior to
111 drying in an oven at 40°C .

112 Next, 200 μL of urine, whole blood or plasma, 15 mg of lung tissue, or 10 mg of hair were added to
113 quartz tubes containing 10 μL of the internal standard solution (10 $\mu\text{g}/\text{mL}$ gallium and iridium, and
114 100 $\mu\text{g}/\text{mL}$ indium and scandium). Two hundred microliters of nitric acid and 200 μL of hydrogen
115 peroxide were then added. The tubes were capped, transferred to the microwave reaction chamber
116 (Ultrawave, Milestone, Sorisole, Italy) and then microwaved at 1500 W (heating from ambient
117 temperature to 220°C over 15 min, followed maintenance at 220°C for 10 min) at a pressure of 110
118 bar. After the samples had cooled, they were transferred to 15 mL polypropylene tubes and made up
119 to a volume of 6 ml with deionized water.

120

121 **2.4. Instrumentation and the analytical procedure**

122 The samples were handled using an ASX-520 autosampler (CETAC technologies, Omaha, NE,
123 USA), a PFA-ST microflow nebulizer, and a PC³ Peltier-cooled cyclonic quartz chamber (both
124 from Elemental Scientific Instruments, Ltd, Birmingham, UK) maintained at +2°C. A demountable
125 quartz torch with a quartz injector (internal diameter: 1.75 mm), a platinum sampler, and skimmer
126 cones were used (Elemental Scientific Instruments, Ltd). The ICP-MS instrument was an Element
127 XR (ThermoFisher, Les Ulis, France) controlled with Element ICP-MS software (v3.1.2.242). The
128 operating conditions (torch position, lenses, gas flows and detector voltage) were optimized daily in
129 low-, medium- and high-resolution modes, using a 100 ppt tuning solution (ThermoFisher). This
130 yielded oxide levels ($^{238}\text{U}^{16}\text{O}/^{238}\text{U}$) below 10%, and a resolution of around 4000 and 10000 in the
131 medium- and high-resolution modes, respectively. Mass calibration was performed as required. The
132 main ICP-MS detection parameters are shown in Supplementary Table 1. The parameters used to
133 detect the elements of interest and their internal standards are summarized in Supplementary Table
134 2.

136 **2.5. Validation of the ICP-MS method**

137 The ICP-MS method was validated using reference standards (at two different concentrations) for
138 whole blood, urine, and hair. Since theoretical concentrations were not available for all 38 elements
139 in the matrix, a set of in-house QC samples at three concentrations (containing the elements spiked
140 into blank water) were also analysed. To assess intra- and interday performance levels, all QC
141 samples were analysed on three different days as six replicates. Calibration curves included a
142 sample blank, a zero sample, and 7 to 15 calibration standards (depending on the element) over a
143 preselected concentration range for each element (based on the literature data for the different
144 matrices [3, 7, 13-16]). The intensity of each element in the sample blank was subtracted from the
145 intensity measured in each sample.

146 For each element, the ratio between the peak area and the peak area of the corresponding internal
147 standard was plotted against the concentration; the relationship was then probed in a regression
148 analysis. The correlation coefficient was analysed for each calibration curve. The precision was
149 defined as the coefficient of variation (CV), which was determined for each QC and had to be less
150 than $\pm 15\%$. The lower limit of quantification (LLOQ) was defined as the calibration standard that
151 gave a signal intensity of at least ten times the standard deviation recorded for sample blanks.

152

153 **2.6. Analysis of clinical trial samples**

154 To confirm its suitability for clinical samples, the method developed here was used to measure
155 elements in whole blood, hair and lung samples from 25 patients participating in a clinical trial
156 (designed to assess the role of trace elements in lung cancer; NCT01949181).

157 3. RESULTS AND DISCUSSION

158 3.1. Sample preparation

159 A variety of vessels and reagent mixtures were tested for microwave mineralization. Disposable
160 borosilicate glassware contaminated samples with several elements, whereas quartz tubes provided
161 reproducible results and low levels of contamination (results not shown). The composition of the
162 mineralization mixture was also optimized by comparing 100, 200 or 400 μL HNO_3 in the presence
163 of absence of 100 or 200 μL of H_2O_2 for the mineralization of 200 μL of sample matrix. The
164 composition with 200 μL HNO_3 and 200 μL H_2O_2 yielded the most complete digestion (with the
165 absence of particulate matter and a sufficient amount of sample) and so was used for the subsequent
166 experiments. This digestion method was found to be appropriate for all samples: whole blood,
167 urine, hair, or lung tissue. In contrast to conventional dilution methods, the microwave
168 mineralization method destroys organic molecules in the matrix; this avoids the formation of
169 deposits on the cones, reduces fouling of the instrument, and therefore increases the sensitivity.

170

171 3.2. ICP-MS analysis

172 Most elements were detected in low-resolution mode. However, polyatomic or isobaric
173 interferences (due to the environment or the sample preparation) occurred for some other elements.
174 Hence, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn and Tl had to be detected in medium-resolution mode, and
175 Ge, As, Se and Pd had to be detected in high-resolution mode [6]. Although a higher resolution
176 improved the method's specificity, the transmission was about 10% in medium-resolution mode and
177 1.5% in high-resolution; this decreased the sensitivity. However, our method was sensitive enough
178 to detect all the elements at the required concentrations.

179 We also optimized the number of runs and passes, which therefore modified the sample volume and
180 the sensitivity. With our final acquisition parameters (2 runs, 2 passes, and the sample parameters

181 described in Supplementary Table 2), the total run time was 3.8 min per sample, and the sample
182 volume was 2 mL.

183

184 **3.3. Validation of the method**

185 The LLOQ and calibration curve were selected to cover the range of concentrations described in
186 human whole blood, urine or hair samples [3, 7, 13-16]. The LLOQ and ULOQ for each element
187 are given in Table 1. Some of the elements analyzed here (such as U, Ru and Hf) are not at all
188 abundant in human samples (i.e. pM concentrations), while others (such as Cu and Zn) are quite
189 abundant (μM concentrations). Hence, the dynamic range was different for each element (from 1.3-
190 to 7.0-log), with LLOQ ranging from 0.1 pM (Hf) to 10 μM (Zn). The regression was linear for all
191 elements other than ^{205}Tl , for which quadratic regression was used. The correlation coefficient for
192 calibration curves (analyzed on 6 different days) ranged from 0.9963 to 0.9999. For each element,
193 the LLOQ, ULOQ, number of calibration standards, and the calibration curve's slope, y-intercept
194 and correlation coefficient are shown in Table 1.

195 The measured concentrations and precision for the intraday and interday analysis of external QC
196 samples (whole blood, urine and hair) and internal QC samples are detailed in Tables 2-5. The
197 intraday, interday or total precision was always below 15%. The method developed here was
198 therefore highly precise for the determination of all 38 tested elements over a wide range of
199 concentrations and in all matrices.

200

201 **3.4. Analysis of clinical trial samples**

202 The results for samples from 25 clinical trial participants are shown in the Figure. The method was
203 suitable for the analysis of clinical samples of whole blood, hair or lung tissue.

204

205 **4. CONCLUSION**

206 Here, we describe a method for the quantification of metals and metalloids in human samples of
207 whole blood, urine, hair and tissues. The method has a number of advantages over previously
208 described methods: the simultaneous analysis of 38 elements, microwave mineralization, high
209 sensitivity, high precision, and a broad dynamic range that can be customized for each element.
210 Furthermore, the method was found to be suitable for the analysis of human samples from clinical
211 trial participants over the whole concentration range reported in these matrices.

212

213 **5. ACKNOWLEDGEMENTS**

214 None

215

216 **6. DISCLOSURE OF CONFLICTS OF INTEREST**

217 The authors declare no conflicts of interest.

218

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223 Paris).

224

225 **8. TABLES**

226

Table 1: Limits of quantification and characteristics of the calibration curve for each element ($n = 6$, values are quoted as the mean \pm standard deviation).

Element	LLOQ (μM)	ULOQ (μM)	Range of the calibration curve (Log)	Number of calibration standards	Slope of the calibration curve	y-intercept of the calibration curve	Correlation coefficient for the calibration curve
Ag	0.015	10	2.8	10	0.92 ± 0.09	0.010 ± 0.015	0.9994 ± 0.0007
As	0.01	1	2.0	7	0.09 ± 0.01	-0.0015 ± 0.0033	0.9987 ± 0.0016
Au	0.01	1	2.0	10	0.72 ± 0.05	0.0014 ± 0.0034	0.9972 ± 0.0028
Ba	0.002	5	3.4	8	0.47 ± 0.03	-0.0032 ± 0.0103	0.9987 ± 0.0009
Be	0.01	0.5	1.7	7	0.01 ± 0.0008	-0.000005 ± 0.00001	0.9990 ± 0.0013
Bi	0.004	1	2.4	8	4.2 ± 0.5	0.0016 ± 0.017	0.9988 ± 0.0023
Cd	0.005	10	3.3	11	0.17 ± 0.01	-0.0036 ± 0.0026	0.9995 ± 0.0005
Ce	0.0002	1	3.7	9	3.1 ± 0.3	0.00035 ± 0.0009	0.9998 ± 0.0003
Co	0.001	20	4.3	12	3.0 ± 1.0	0.12 ± 0.11	0.9993 ± 0.0005
Cr	0.02	10	2.7	8	2.3 ± 0.8	0.025 ± 0.023	0.9999 ± 0.0002
Cs	0.002	1	2.7	8	3.16 ± 0.17	0.0052 ± 0.0081	0.9996 ± 0.0005
Cu	5	200	1.6	15	2.0 ± 0.7	0.058 ± 1.89	0.9986 ± 0.0011
Fe	1	500	2.7	15	3.1 ± 1.1	3.1 ± 2.0	0.9997 ± 0.0002
Ge	0.01	1	2.0	7	0.21 ± 0.02	-0.0011 ± 0.0012	0.9991 ± 0.0005
Hf	0.0000001	1	7.0	15	1.0 ± 0.1	-0.0052 ± 0.0032	0.9983 ± 0.0012
Hg	0.025	10	2.6	11	0.2 ± 0.01	0.0020 ± 0.0026	0.9996 ± 0.0003
La	0.00005	1	4.3	11	32.5 ± 3.0	-0.0089 ± 0.0030	0.9998 ± 0.0002
Mn	0.05	2	1.6	10	3.5 ± 1.2	0.0041 ± 0.018	0.9996 ± 0.0002
Mo	0.005	1.5	2.5	11	0.24 ± 0.02	-0.0007 ± 0.0002	0.9994 ± 0.0002
Ni	0.05	50	3.0	15	0.76 ± 0.27	0.041 ± 0.041	0.9998 ± 0.0001
Pb	0.025	5	2.3	7	3.0 ± 0.7	-0.038 ± 0.096	0.9991 ± 0.0010
Pd	0.005	0.5	2.0	7	0.25 ± 0.04	-0.00062 ± 0.00053	0.9963 ± 0.0029

ICP-MS method for human samples

Pt	0.001	0.1	2.0	10	0.76 ± 0.02	-0.00006 ± 0.0002	0.9997 ± 0.0002
Rb	0.1	50	2.7	10	1.2 ± 0.1	0.85 ± 0.42	0.9996 ± 0.0018
Ru	0.000001	0.01	4.0	13	0.40 ± 0.03	0.00002 ± 0.000007	0.9994 ± 0.0010
Sb	0.00001	0.1	4.0	10	0.52 ± 0.05	-0.0001 ± 0.0005	0.9975 ± 0.0011
Se	0.1	10	2.0	11	0.02 ± 0.003	-0.021 ± 0.029	0.9989 ± 0.0010
Sn	0.005	1	2.3	11	0.70 ± 0.04	-0.0019 ± 0.0005	0.9994 ± 0.0004
Sr	0.1	10	2.0	7	1.79 ± 0.11	0.012 ± 0.046	0.9997 ± 0.0002
Te	0.001	0.05	1.7	7	0.03 ± 0.003	-0.000004 ± 0.000009	0.9991 ± 0.0008
Th	0.00025	0.01	1.6	7	3.9 ± 0.3	-0.00004 ± 0.0001	0.9981 ± 0.0012
Ti	0.038	10	2.4	7	0.17 ± 0.003	0.0013 ± 0.0038	0.9998 ± 0.0002
Tl	0.00025	0.05	2.3	7		Quadratic regression	
U	0.000001	0.001	3.0	15	49.6 ± 3.3	-0.00002 ± 0.00008	0.9995 ± 0.0003
V	0.02	1.5	1.9	9	2.2 ± 0.8	-0.026 ± 0.097	0.9996 ± 0.0003
W	0.0004	1	3.4	8	1.0 ± 0.2	-0.00007 ± 0.0019	0.9999 ± 0.0001
Zn	10	200	1.3	7	0.27 ± 0.10	0.066 ± 0.20	0.9990 ± 0.0007
Zr	0.00001	0.1	4.0	15	0.90 ± 0.06	-0.0013 ± 0.0019	0.9968 ± 0.0019

Table 2: Validation data for whole blood QC samples. Measured concentrations are presented for three different days as the median [range] (μM) from six replicate samples. The values of the CVs correspond to the intraday, interday and total CVs, respectively.

	Blood level 1: QM-B-Q1505			Blood level 2: QM-B-Q1506		
	Theoretical concentration	Measured concentration	CV (%)	Theoretical concentration	Measured concentration	CV (%)
Ag	0.022	0.023 [0.022-0.024]	5.1	0.061	0.062 [0.057-0.065]	6.9
		0.024 [0.023-0.025]	14.9		0.063 [0.062-0.078]	7.9
		0.022 [0.019-0.023]	7.1		0.063 [0.058-0.066]	7.0
As	0.036	0.044 [0.037-0.047]	8.8	0.21	0.24 [0.20-0.29]	12.2
		0.044 [0.037-0.050]	7.4		0.23 [0.21-0.25]	7.9
		0.041 [0.038-0.042]	8.7		0.24 [0.21-0.27]	11.8
Ba	0.026	0.048 [0.046-0.049]	6.5	0.058	0.076 [0.075-0.079]	2.6
		0.042 [0.040-0.048]	13.6		0.082 [0.078-0.085]	9.4
		0.043 [0.041-0.049]	7.7		0.078 [0.077-0.080]	4.1
Be	0.30	0.45 [0.44-0.48]	4.6	1.9	2.8 [2.7-2.9]	4.2
		0.42 [0.38-0.45]	13.0		2.8 [2.6-2.8]	7.2
		0.42 [0.39-0.43]	6.3		2.7 [2.3-2.8]	4.6
Bi	0.013	0.013 [0.011-0.016]	9.3	0.034	0.035 [0.026-0.039]	14.4
		0.014 [0.014-0.015]	14.2		0.038 [0.035-0.044]	14.5
		0.013 [0.012-0.014]	10.0		0.035 [0.030-0.047]	14.4
Cd	0.053	0.061 [0.057-0.066]	5.7	0.12	0.13 [0.13-0.14]	4.8
		0.061 [0.052-0.066]	9.3		0.13 [0.12-0.14]	4.5
		0.057 [0.055-0.058]	6.3		0.13 [0.12-0.14]	4.8
Co	0.019	0.018 [0.017-0.019]	6.9	0.035	0.035 [0.033-0.037]	6.3
		0.021 [0.018-0.022]	14.6		0.032 [0.031-0.034]	11.0
		0.020 [0.017-0.022]	8.3		0.034 [0.030-0.039]	7.0

Cr	0.096	0.090 [0.066-0.102]	14.4	0.11	0.10 [0.09-0.10]	7.8
		0.094 [0.076-0.106]	12.0		0.11 [0.10-0.12]	14.2
		0.086 [0.079-0.108]	14.1		0.10 [0.10-0.12]	8.9
Cu	12.8	12.2 [11.8-12.7]	9.5	47.8	40.0 [38.2-40.9]	2.6
		13.1 [8.7-13.8]	15.0		39.3 [38.1-39.8]	2.6
		11.0 [10.8-11.3]	10.3		40.2 [38.2-41.3]	2.6
Hg	0.030	0.038 [0.036-0.041]	3.7	0.008	0.010 [0.009-0.011]	12.1
		0.036 [0.035-0.037]	9.3		0.010 [0.009-0.011]	0.9
		0.039 [0.038-0.039]	4.8		0.010 [0.008-0.012]	11.0
Mn	0.28	0.28 [0.26-0.30]	6.5	0.41	0.40 [0.38-0.43]	4.5
		0.27 [0.26-0.30]	6.0		0.39 [0.37-0.41]	6.4
		0.26 [0.25-0.31]	6.4		0.41 [0.37-0.44]	4.8
Mo	0.031	0.075 [0.056-0.086]	12.3	0.051	0.090 [0.071-0.093]	12.6
		0.076 [0.067-0.079]	14.7		0.077 [0.062-0.093]	13.8
		0.063 [0.056-0.082]	12.7		0.086 [0.065-0.089]	12.8
Ni	<LLOQ	NA	NA	0.18	0.15 [0.14-0.22]	11.9
					0.16 [0.13-0.17]	10.5
					0.17 [0.17-0.18]	11.7
Pb	1.1	1.0 [0.9-1.1]	6.3	2.4	2.1 [1.9-2.3]	4.8
		1.0 [1.0-1.0]	3.6		2.1 [2.0-2.2]	3.2
		1.0 [0.9-1.0]	6.1		2.0 [1.9-2.2]	4.6
Pt	0.0021	0.0022 [0.0019-0.0023]	9.4	0.012	0.014 [0.013-0.015]	3.6
		0.0020 [0.0019-0.0026]	12.7		0.014 [0.013-0.014]	5.2
		0.0020 [0.0018-0.0020]	9.9		0.013 [0.013-0.014]	3.9
Sb	0.029	0.033 [0.031-0.036]	9.7	0.11	0.13 [0.12-0.13]	2.0
		0.035 [0.023-0.037]	6.5		0.12 [0.12-0.13]	6.8
		0.032 [0.031-0.033]	9.3		0.13 [0.12-0.13]	3.0

Se	2.2	2.2 [2.1-2.5]	10.2	2.9	3.1 [2.7-3.5]	11.3
		2.5 [2.1-2.7]	12.5		2.7 [2.5-3.4]	13.6
		2.7 [2.2-2.8]	10.5		3.1 [2.7-3.5]	11.6
Sn	0.029	0.032 [0.027-0.037]	14.9	0.17	0.15 [0.14-0.16]	6.3
		0.032 [0.021-0.038]	6.9		0.16 [0.13-0.18]	4.5
		0.032 [0.029-0.038]	14.2		0.16 [0.15-0.17]	6.1
Sr	1.0	1.2 [1.1-1.2]	3.0	3.2	3.6 [3.4-3.8]	3.2
		1.1 [1.1-1.2]	4.1		3.5 [3.4-3.6]	5.0
		1.2 [1.1-1.2]	3.2		3.5 [3.3-3.6]	3.5
Te	0.020	0.021 [0.020-0.022]	6.4	0.062	0.064 [0.059-0.066]	3.8
		0.021 [0.020-0.022]	6.3		0.066 [0.064-0.069]	11.5
		0.019 [0.019-0.023]	6.4		0.069 [0.066-0.073]	5.3
Th	0.0029	0.0032 [0.0030-0.0035]	3.7	0.0086	0.0101 [0.0091-0.0103]	3.4
		0.0033 [0.0032-0.0033]	1.6		0.0100 [0.0098-0.0102]	2.3
		0.0033 [0.0032-0.0033]	3.5		0.0100 [0.0096-0.0102]	3.3
Tl	0.017	0.016 [0.016-0.017]	2.7	0.038	0.034 [0.031-0.036]	3.9
		0.015 [0.015-0.016]	8.3		0.036 [0.035-0.038]	7.8
		0.017 [0.016-0.017]	3.8		0.036 [0.034-0.036]	4.5
U	0.0020	0.0020 [0.0019-0.0021]	5.8	0.0035	0.0035 [0.0034-0.0039]	4.7
		0.0018 [0.0017-0.0018]	12.8		0.0038 [0.0035-0.0039]	13.9
		0.0019 [0.0018-0.0023]	7.0		0.0034 [0.0033-0.0035]	6.6
V	0.024	0.036 [0.030-0.040]	6.4	0.052	0.059 [0.055-0.064]	5.3
		0.038 [0.037-0.041]	10.4		0.058 [0.054-0.060]	4.9
		0.039 [0.036-0.040]	7.0		0.060 [0.055-0.064]	5.3
Zn	97	112 [106-117]	4.8	166	176 [156-182]	5.2
		113 [101-118]	11.5		178 [170-189]	7.8
		101 [99-107]	6.1		186 [165-193]	5.6

Table 3: Validation data for urine QC samples. The measured concentrations are presented for the three different days as the median [range] (μM) from 6 replicate samples. The values of the CVs correspond to the intraday, interday and total CVs, respectively.

	Urine level 1: QM-U-Q1503			Urine level 2: QM-U-Q1504		
	Theoretical concentration	Measured concentration	CV (%)	Theoretical concentration	Measured concentration	CV (%)
Ag	0.051	0.045 [0.040-0.047] 0.049 [0.047-0.051] 0.047 [0.040-0.049]	5.8 12.8 7.1	< LLOQ	NA	NA
As	1.3	1.4 [1.2-1.5] 1.5 [1.4-1.5] 1.4 [1.3-1.6]	7.7 8.8 7.8	0.67	0.77 [0.72-0.81] 0.74 [0.64-0.84] 0.67 [0.63-0.76]	9.0 14.5 9.9
Ba	0.031	0.047 [0.045-0.051] 0.046 [0.042-0.048] 0.053 [0.046-0.054]	6.3 12.6 7.4	0.012	0.038 [0.037-0.039] 0.033 [0.029-0.039] 0.031 [0.030-0.046]	13.8 14.6 13.9
Be	0.30	0.40 [0.39-0.44] 0.40 [0.39-0.41] 0.39 [0.37-0.44]	4.9 4.5 4.8	1.4	2.0 [1.8-2.0] 2.0 [1.8-2.1] 1.9 [1.7-2.0]	4.6 9.2 5.4
Bi	0.12	0.11 [0.10-0.13] 0.12 [0.09-0.13] 0.10 [0.09-0.14]	14.7 11.8 14.3	0.025	0.031 [0.027-0.031] 0.026 [0.025-0.036] 0.031 [0.024-0.031]	11.4 5.7 10.9
Cd	0.14	0.16 [0.15-0.16] 0.15 [0.15-0.16] 0.15 [0.15-0.16]	2.4 2.7 2.5	0.026	0.022 [0.021-0.028] 0.023 [0.022-0.031] 0.027 [0.019-0.029]	14.9 10.8 14.4
Co	0.14	0.15 [0.13-0.16] 0.14 [0.13-0.15] 0.15 [0.15-0.16]	5.0 11.4 6.1	0.035	0.035 [0.034-0.042] 0.039 [0.038-0.043] 0.039 [0.035-0.040]	6.2 10.3 6.8

Cr	0.093	0.095 [0.081-0.106]	14.6	0.41	0.46 [0.44-0.47]	6.5
		0.087 [0.083-0.126]	13.8		0.44 [0.38-0.49]	14.7
		0.105 [0.079-0.118]	14.5		0.41 [0.39-0.43]	8.0
Cu	0.14	0.13 [0.13-0.14]	8.0	17.0	16.3 [16.1-16.6]	3.7
		0.14 [0.13-0.17]	14.9		17.6 [16.2-18.9]	10.6
		0.15 [0.14-0.18]	9.3		16.2 [15.9-17.3]	5.1
Hg	0.066	0.039 [0.031-0.040]	14.9	0.17	0.15 [0.15-0.17]	4.6
		0.030 [0.027-0.042]	14.7		0.15 [0.14-0.16]	6.4
		0.034 [0.028-0.041]	14.9		0.15 [0.15-0.17]	4.9
Mn	0.099	0.098 [0.084-0.110]	6.8	0.049	0.049 [0.045-0.054]	7.1
		0.096 [0.093-0.103]	12.9		0.054 [0.045-0.059]	10.0
		0.089 [0.085-0.093]	7.8		0.053 [0.051-0.054]	7.5
Mo	0.63	0.72 [0.67-0.76]	4.8	2.9	3.3 [3.2-3.4]	3.8
		0.70 [0.63-0.73]	6.2		3.3 [3.1-3.5]	9.3
		0.68 [0.67-0.71]	5.0		3.1 [2.9-3.3]	4.8
Ni	0.27	0.27 [0.23-0.36]	12.2	0.18	0.14 [0.13-0.20]	11.5
		0.29 [0.26-0.37]	9.5		0.16 [0.13-0.17]	3.7
		0.31 [0.29-0.32]	11.9		0.16 [0.15-0.16]	10.8
Pb	0.34	0.31 [0.30-0.32]	7.0	0.80	0.64 [0.61-0.68]	3.6
		0.30 [0.24-0.33]	5.0		0.67 [0.65-0.71]	9.3
		0.30 [0.29-0.34]	6.8		0.63 [0.60-0.65]	4.6
Pt	0.0056	0.0051 [0.0050-0.0054]	4.9	0.010	0.009 [0.008-0.009]	4.3
		0.0056 [0.0050-0.0057]	10.2		0.010 [0.009-0.010]	14.9
		0.0055 [0.0053-0.0060]	5.8		0.010 [0.010-0.011]	6.5
Sb	0.015	0.016 [0.014-0.016]	6.5	0.056	0.063 [0.060-0.066]	6.5
		0.017 [0.016-0.019]	14.3		0.057 [0.050-0.060]	14.9
		0.017 [0.016-0.019]	7.8		0.057 [0.056-0.065]	8.0

Se	3.9	4.6 [4.1-5.3]	9.0	1.5	1.8 [1.6-2.0]	13.4
		4.2 [3.9-4.5]	13.3		1.8 [1.2-2.1]	14.8
		4.2 [4.0-4.6]	9.6		1.6 [1.5-1.8]	13.6
Sn	0.21	0.22 [0.20-0.24]	3.5	0.020	0.018 [0.016-0.020]	9.0
		0.24 [0.24-0.25]	13.7		0.017 [0.016-0.019]	5.2
		0.25 [0.24-0.25]	5.9		0.017 [0.016-0.020]	8.7
Te	0.21	0.21 [0.19-0.22]	4.5	0.032	0.032 [0.031-0.034]	6.1
		0.22 [0.21-0.24]	9.7		0.032 [0.029-0.035]	9.8
		0.21 [0.20-0.22]	5.4		0.029 [0.028-0.033]	6.6
Th	0.00040	0.00038 [0.00036-0.00042]	6.5	0.0013	0.0015 [0.0015-0.0016]	4.8
		0.00042 [0.0004-0.00043]	14		0.0015 [0.0014-0.0017]	6.9
		0.00037 [0.00033-0.00042]	7.9		0.00145 [0.0014-0.0015]	5.1
Tl	0.12	0.11 [0.10-0.11]	5.6	0.048	0.041 [0.040-0.042]	3.6
		0.11 [0.10-0.12]	8.3		0.044 [0.041-0.046]	7.5
		0.11 [0.11-0.12]	6.0		0.041 [0.040-0.044]	4.2
U	0.0044	0.0037 [0.0036-0.0038]	4.1	0.0020	0.0017 [0.0016-0.0020]	7.3
		0.0039 [0.0036-0.0042]	6.5		0.0018 [0.0016-0.0019]	4.2
		0.0037 [0.0036-0.0038]	4.4		0.0017 [0.0016-0.0019]	7.0
V	0.35	0.41 [0.37-0.42]	3.4	0.12	0.13 [0.13-0.14]	6.4
		0.37 [0.37-0.39]	12.5		0.13 [0.12-0.15]	3.6
		0.36 [0.35-0.37]	5.5		0.13 [0.12-0.14]	6.1
Zn	8.8	8.9 [8.5-11.2]	11.8	16.8	18.8 [15.6-22.0]	12.5
		9.2 [8.0-10.0]	6.4		19.3 [17.4-23.0]	4.0
		9.4 [8.3-10.9]	11.3		18.9 [17.2-20.0]	11.8

Table 4: Validation data for hair QC samples. The measured concentrations are presented for the three different days as the median [range] ($\mu\text{mol/g}$) from 6 replicate samples. The values of the CVs correspond to the intraday, interday and total CVs, respectively.

	Hair level 1: QM-H-Q1315			Hair level 2: QM-H-Q1406		
	Theoretical concentration	Measured concentration	CV (%)	Theoretical concentration	Measured concentration	CV (%)
Ag	0.014	0.016 [0.016-0.017]	5.0	0.0029	0.0032 [0.0032-0.0033]	1.9
		0.016 [0.014-0.017]	5.2		0.0033 [0.0032-0.0034]	11.3
		0.016 [0.015-0.016]	5.1		0.0030 [0.0030-0.0031]	4.3
As	0.0081	0.0088 [0.0085-0.0098]	7.0	0.0080	0.0090 [0.0084-0.0091]	2.9
		0.0089 [0.0085-0.0106]	8.0		0.0080 [0.0076-0.0084]	14.6
		0.0085 [0.0082-0.0093]	7.1		0.0080 [0.0078-0.0082]	5.7
Ba	0.13	0.14 [0.14-0.14]	4.3	0.020	0.020 [0.019-0.021]	3.6
		0.13 [0.12-0.14]	14.5		0.019 [0.019-0.02]	5.2
		0.12 [0.12-0.13]	6.4		0.002 [0.019-0.021]	3.8
Be	0.045	0.054 [0.043-0.056]	8.7	0.027	0.031 [0.029-0.033]	3.6
		0.049 [0.047-0.055]	9.8		0.027 [0.027-0.028]	13.8
		0.047 [0.044-0.049]	8.8		0.029 [0.028-0.031]	5.9
Bi	0.0078	0.0087 [0.0086-0.0090]	3.1	0.0029	0.0032 [0.0031-0.0035]	4.2
		0.0080 [0.0077-0.0084]	14.6		0.0029 [0.0028-0.0031]	12.0
		0.0078 [0.0076-0.0082]	6.0		0.0031 [0.0030-0.0032]	5.7
Cd	0.018	0.019 [0.019-0.020]	3.9	0.014	0.014 [0.014-0.015]	3.0
		0.018 [0.017-0.002]	11.9		0.014 [0.014-0.015]	3.5
		0.017 [0.017-0.019]	5.5		0.014 [0.014-0.015]	3.1
Co	0.046	0.039 [0.038-0.041]	4.9	0.042	0.037 [0.036-0.038]	2.1
		0.040 [0.039-0.040]	1.5		0.037 [0.036-0.038]	0.8
		0.039 [0.036-0.045]	4.6		0.037 [0.035-0.038]	2.0

Cr	0.0087	0.0095 [0.0077-0.0096]	7.1	0.037	0.035 [0.034-0.036]	4.9
		0.0089 [0.0085-0.0094]	13.0		0.034 [0.029-0.035]	10.9
		0.0097 [0.0090-0.0104]	8.0		0.035 [0.035-0.036]	6.0
Cu	0.29	0.25 [0.24-0.26]	3.2	0.94	0.80 [0.79-0.82]	1.1
		0.25 [0.24-0.26]	3.1		0.80 [0.79-0.80]	0.9
		0.26 [0.24-0.26]	3.2		0.79 [0.79-0.81]	1.1
Hg	0.010	0.012 [0.011-0.013]	4.3	0.019	0.020 [0.020-0.021]	2.5
		0.011 [0.010-0.011]	13.8		0.020 [0.020-0.021]	3.8
		0.010 [0.010-0.011]	6.2		0.021 [0.020-0.022]	2.7
Mn	0.084	0.072 [0.069-0.073]	4.3	0.10	0.085 [0.084-0.086]	1.2
		0.074 [0.071-0.078]	5.6		0.085 [0.083-0.086]	1.3
		0.070 [0.067-0.078]	4.4		0.085 [0.085-0.087]	1.2
Mo	0.0087	0.0100 [0.0100-0.0110]	5.3	0.0038	0.0037 [0.0035-0.0039]	8.4
		0.0093 [0.0085-0.0099]	13.9		0.0036 [0.0043-0.0041]	13.8
		0.0091 [0.0084-0.0094]	6.9		0.0041 [0.0035-0.0046]	9.2
Ni	0.022	0.020 [0.018-0.02]	3.1	0.12	0.111 [0.109-0.114]	2.0
		0.018 [0.018-0.02]	4.0		0.111 [0.108-0.112]	1.9
		0.019 [0.019-0.02]	3.2		0.111 [0.105-0.112]	2.0
Pb	0.0074	0.0080 [0.0079-0.0082]	3.5	0.015	0.015 [0.014-0.015]	2.5
		0.0075 [0.0071-0.0080]	9.2		0.014 [0.013-0.014]	7.0
		0.0076 [0.0074-0.0082]	4.6		0.015 [0.014-0.015]	3.3
Pt	0.000087	0.000096 [0.000094-0.000098]	4.9	0.0012	0.0012 [0.0011-0.0012]	2.0
		0.000087 [0.000080-0.000093]	14.6		0.0011 [0.0011-0.0012]	8.6
		0.000087 [0.000082-0.000091]	6.8		0.0012 [0.0012-0.0013]	3.5
Sb	0.0076	0.0089 [0.0079-0.0092]	5.9	0.010	0.011 [0.010-0.011]	5.1
		0.0085 [0.0078-0.0093]	7.0		0.010 [0.010-0.011]	7.8
		0.0081 [0.0080-0.0088]	6.0		0.010 [0.010-0.011]	5.5

Se	0.038	0.041 [0.039-0.045]	5.6	0.013	0.012 [0.012-0.015]	5.7
		0.041 [0.039-0.046]	5.5		0.012 [0.012-0.012]	14.8
		0.044 [0.043-0.046]	5.6		0.014 [0.013-0.014]	7.5
Sn	0.050	0.069 [0.067-0.072]	4.7	0.052	0.073 [0.069-0.077]	3.2
		0.066 [0.062-0.069]	11.8		0.071 [0.070-0.073]	5.9
		0.063 [0.059-0.068]	6.0		0.074 [0.072-0.078]	3.6
Te	0.0042	0.0048 [0.0047-0.0048]	4.9	0.0055	0.0062 [0.0061-0.0063]	2.3
		0.0045 [0.0040-0.0048]	14.4		0.0058 [0.0056-0.0061]	10.5
		0.0041 [0.0041-0.0046]	6.7		0.0057 [0.0056-0.0060]	4.2
Th	0.011	0.017 [0.016-0.018]	5.4	0.023	0.029 [0.027-0.031]	2.8
		0.016 [0.015-0.017]	13.6		0.030 [0.030-0.031]	7.8
		0.016 [0.015-0.017]	6.9		0.029 [0.028-0.029]	3.7
Tl	0.0011	0.0012 [0.0011-0.0012]	4.4	0.00045	0.00049 [0.00047-0.00049]	1.9
		0.0011 [0.0010-0.0012]	13.6		0.00047 [0.00046-0.00048]	5.1
		0.0011 [0.0010-0.0011]	6.4		0.00047 [0.00046-0.00047]	2.5
U	0.0021	0.0025 [0.0023-0.0025]	5.0	0.0015	0.0016 [0.0016-0.0017]	2.3
		0.0024 [0.0023-0.0026]	9.0		0.0016 [0.0016-0.0017]	0.3
		0.0023 [0.0021-0.0025]	5.6		0.0016 [0.0016-0.0017]	2.1
V	0.024	0.020 [0.020-0.021]	4.5	0.014	0.012 [0.012-0.013]	5.4
		0.020 [0.020-0.022]	1.6		0.012 [0.011-0.014]	1.1
		0.019 [0.019-0.022]	4.2		0.012 [0.012-0.012]	5.1
Zn	3.4	3.7 [3.6-3.9]	2.8	4.9	5.0 [4.9-5.1]	3.3
		3.8 [3.6-4.0]	3.5		4.9 [4.8-5.2]	5.5
		3.7 [3.6-3.7]	2.9		5.2 [4.8-5.4]	3.6

Table 5: Validation data for internal QC samples. The measured concentrations are presented for the three different days as the median [range] (μM) from 6 replicate samples. The values of the CVs correspond to the intraday, interday and total CVs, respectively.

Internal QC level 1			Internal QC level 2			Internal QC level 3						
Theoretical concentration	Measured concentration	CV (%)	Theoretical concentration	Measured concentration	CV (%)	Theoretical concentration	Measured concentration	CV (%)				
Ag	0.75	0.47 [0.47-0.48]	1.7	2.4 [2.3-2.4]	2.0	7.5	7.8 [7.3-8.8]	10.9				
		0.45 [0.44-0.47]							2.6 [2.5-2.6]	14	7.9 [6.2-8.2]	10.7
		0.46 [0.45-0.47]							2.7 [2.6-2.7]	5.3	7.1 [6.0-7.9]	10.9
As	0.075	0.083 [0.077-0.095]	7.8	0.29 [0.26-0.30]	11.5	0.75	0.86 [0.79-0.93]	9.9				
		0.086 [0.078-0.092]							0.31 [0.22-0.33]	1.8	0.90 [0.71-1.00]	1.1
		0.075 [0.069-0.087]							0.29 [0.25-0.31]	10.8	0.87 [0.76-0.91]	9.2
Au	0.075	0.073 [0.068-0.075]	4.0	0.23 [0.20-0.30]	9.9	0.75	0.80 [0.78-0.84]	3.9				
		0.068 [0.067-0.071]							0.25 [0.24-0.26]	8.3	0.79 [0.77-0.80]	11.5
		0.069 [0.060-0.070]							0.26 [0.22-0.26]	9.7	0.72 [0.68-0.80]	5.5
Ba	0.38	0.40 [0.38-0.41]	2.8	1.3 [1.2-1.3]	3.2	3.8	3.9 [3.8-4.0]	4.0				
		0.41 [0.40-0.42]							1.3 [1.2-1.3]	4.0	3.9 [3.6-4.2]	5.6
		0.40 [0.39-0.40]							1.3 [1.2-1.3]	3.3	4.0 [3.9-4.3]	4.2
Be	0.038	0.039 [0.036-0.041]	4.7	0.12 [0.11-0.13]	4.2	0.38	0.41 [0.38-0.44]	4.9				
		0.041 [0.037-0.043]							0.12 [0.12-0.13]	14.0	0.39 [0.38-0.40]	9.8
		0.042 [0.042-0.046]							0.13 [0.13-0.13]	6.2	0.37 [0.35-0.40]	5.7
Bi	0.075	0.080 [0.079-0.083]	1.5	0.27 [0.26-0.27]	2.6	0.75	0.73 [0.72-0.75]	3.0				
		0.078 [0.076-0.079]							0.26 [0.25-0.26]	9.6	0.73 [0.69-0.76]	8.4
		0.076 [0.075-0.078]							0.25 [0.23-0.25]	4.1	0.77 [0.76-0.80]	4.0
Cd	0.75	0.75 [0.72-0.77]	1.9	2.5 [2.3-2.5]	2.9	7.5	7.0 [6.8-7.2]	3.8				
		0.74 [0.72-0.76]							2.4 [2.3-2.4]	5.0	7.0 [6.6-7.4]	4.6
		0.72 [0.71-0.73]							2.4 [2.2-2.4]	3.2	7.2 [6.9-7.5]	3.9

Ce	0.075	0.075 [0.074-0.077]	1.5	0.25	0.26 [0.25-0.27]	4.2	0.75	0.78 [0.73-0.83]	3.7
		0.077 [0.075-0.078]	2.1		0.26 [0.26-0.29]	8.1		0.79 [0.78-0.81]	3.1
		0.075 [0.074-0.077]	1.6		0.26 [0.24-0.26]	4.8		0.79 [0.76-0.83]	3.6
Co	1.5	1.6 [1.6-1.7]	1.8	5.0	5.6 [5.4-5.7]	2.4	15.0	16.3 [15.0-17.4]	4.2
		1.7 [1.7-1.8]	8.4		5.6 [5.6-5.8]	1.9		16.1 [15.5-16.9]	6.2
		1.7 [1.7-1.8]	3.3		5.7 [5.5-5.9]	2.3		16.9 [16.4-17.4]	4.5
Cr	0.75	0.72 [0.71-0.74]	2.1	2.5	2.4 [2.4-2.5]	2.4	7.5	7.3 [7.1-7.6]	4.1
		0.76 [0.73-0.78]	11.1		2.5 [2.5-2.6]	5.0		7.5 [6.9-8.0]	3.2
		0.78 [0.76-0.82]	4.3		2.6 [2.5-2.6]	2.8		7.4 [7.1-7.5]	4.0
Cs	0.075	0.087 [0.080-0.088]	3.7	0.25	0.29 [0.26-0.30]	3.4	0.75	0.82 [0.79-0.88]	3.1
		0.088 [0.080-0.090]	1.3		0.28 [0.28-0.29]	5.5		0.85 [0.84-0.87]	5.0
		0.085 [0.084-0.086]	3.5		0.28 [0.26-0.28]	3.7		0.86 [0.81-0.90]	3.4
Cu	15.0	15.8 [15.4-15.9]	1.9	50	53 [53-56]	2.3	150	158 [150-163]	4.0
		16.9 [16.4-17.6]	11.7		53 [52-55]	2.6		157 [143-165]	4.3
		17.1 [16.9-17.6]	4.4		53 [51-54]	2.4		160 [156-165]	4.1
Fe	37.5	39.0 [37.2-40.1]	2.2	125	130 [128-135]	2.2	375	366 [329-391]	5.2
		40.1 [39.1-41.8]	6.8		131 [130-138]	2.7		342 [316-360]	10.2
		41.1 [40.3-41.7]	3.1		133 [130-139]	2.2		365 [357-386]	6.1
Ge	0.075	0.082 [0.070-0.095]	7.6	0.25	0.27 [0.26-0.29]	4.3	0.75	0.84 [0.69-1.00]	9.9
		0.086 [0.080-0.090]	5.1		0.29 [0.28-0.29]	9.1		0.87 [0.69-0.97]	3.0
		0.082 [0.078-0.088]	7.2		0.29 [0.26-0.30]	5.1		0.86 [0.75-0.89]	9.3
Hf	0.075	0.092 [0.062-0.096]	9.5	0.25	0.29 [0.23-0.33]	12.8	0.75	0.82 [0.74-0.90]	5.4
		0.086 [0.080-0.091]	3.7		0.29 [0.22-0.29]	5.0		0.84 [0.75-0.86]	4.2
		0.084 [0.077-0.088]	9.0		0.29 [0.22-0.29]	12.2		0.85 [0.82-0.90]	5.3
Hg	0.75	0.87 [0.83-0.87]	1.6	2.5	2.9 [2.8-2.9]	1.2	7.5	7.4 [7.0-7.4]	4
		0.84 [0.82-0.85]	3.6		2.9 [2.8-2.9]	14.9		7.6 [7.0-8.0]	5.5
		0.85 [0.83-0.86]	2.0		2.6 [2.5-2.6]	5.2		7.5 [7.3-7.9]	4.2

ICP-MS method for human samples

La	0.075	0.069 [0.068-0.072]	1.6	0.25	0.24 [0.23-0.25]	3.1	0.75	0.73 [0.71-0.74]	4.1
		0.071 [0.068-0.072]	1.9		0.25 [0.24-0.26]	6.4		0.71 [0.67-0.76]	5.2
		0.070 [0.068-0.071]	1.7		0.24 [0.22-0.24]	3.7		0.75 [0.70-0.78]	4.2
Mn	0.15	0.17 [0.15-0.18]	6.1	0.50	0.58 [0.52-0.60]	4.5	1.5	1.7 [1.6-1.8]	2.7
		0.17 [0.16-0.18]	5.1		0.58 [0.52-0.60]	2.1		1.7 [1.7-1.8]	1.9
		0.17 [0.16-0.18]	6.0		0.57 [0.56-0.60]	4.3		1.7 [1.7-1.8]	2.6
Mo	0.11	0.11 [0.10-0.11]	3.7	0.38	0.35 [0.32-0.37]	3.7	1.1	1.1 [1.0-1.2]	4.5
		0.11 [0.11-0.12]	7.7		0.35 [0.34-0.36]	0.9		1.1 [1.0-1.1]	1.8
		0.11 [0.11-0.11]	4.4		0.35 [0.34-0.36]	3.5		1.1 [1.0-1.2]	4.3
Ni	3.8	3.7 [3.7-3.8]	1.6	12.5	12.6 [12.4-13.1]	2.5	37.5	36.4 [35.7-38.0]	3.9
		3.8 [3.7-3.9]	7.7		12.3 [12.2-12.9]	6.5		39.2 [36.1-41.4]	7.2
		4.0 [3.9-4.0]	3.0		13.1 [12.5-13.6]	3.2		38.5 [37.4-39.5]	4.4
Pb	0.38	0.38 [0.38-0.39]	1.5	1.3	1.2 [1.1-1.2]	2.6	3.8	3.4 [3.3-3.5]	3.5
		0.35 [0.34-0.36]	13.3		1.2 [1.1-1.2]	2.3		3.5 [3.3-3.7]	10.3
		0.35 [0.34-0.36]	4.8		1.2 [1.1-1.2]	2.5		3.2 [3.1-3.4]	4.8
Pd	0.033	0.028 [0.026-0.031]	6.7	0.11	0.10 [0.09-0.10]	6.0	0.38	0.32 [0.30-0.37]	9.6
		0.028 [0.026-0.030]	10.1		0.10 [0.09-0.10]	5.7		0.34 [0.29-0.38]	5.1
		0.030 [0.028-0.034]	7.2		0.10 [0.09-0.11]	6.0		0.31 [0.29-0.39]	9.2
Pt	0.0075	0.0085 [0.0082-0.0086]	1.8	0.025	0.029 [0.028-0.029]	2.2	0.075	0.083 [0.079-0.089]	3.5
		0.0086 [0.0083-0.0088]	2.5		0.029 [0.028-0.029]	3.5		0.083 [0.082-0.083]	1.3
		0.0086 [0.0085-0.0088]	1.9		0.028 [0.027-0.029]	2.4		0.083 [0.081-0.087]	3.3
Rb	3.8	4.0 [3.8-4.2]	2.7	12.5	14.3 [13.7-14.4]	2.9	37.5	35.0 [32.0-36.9]	4.9
		4.0 [3.8-4.1]	6.0		12.8 [12.5-13.4]	14.0		33.5 [32.3-34.4]	5.1
		4.2 [4.1-4.3]	3.3		14.5 [13.5-14.7]	5.5		33.8 [30.0-35.1]	4.9
Ru	0.00075	0.00082 [0.00081-0.00085]	2.3	0.0025	0.0024 [0.0024-0.0025]	3.2	0.0075	0.0077 [0.0073-0.0084]	4.0
		0.00076 [0.00072-0.00077]	14.8		0.0025 [0.0025-0.0026]	5.6		0.0080 [0.0077-0.008]	2.8
		0.00073 [0.00071-0.00076]	5.5		0.0025 [0.0023-0.0026]	3.6		0.0077 [0.0074-0.0081]	3.9

ICP-MS method for human samples

Se	0.75	0.94 [0.86-1.00]	4.2	2.5	2.9 [2.7-3.1]	4.4	7.5	9.1 [8.1-9.7]	5.5
		0.97 [0.92-1.01]	5.9		3.1 [2.8-3.1]	7.4		8.9 [8.6-9.6]	10.1
		0.93 [0.88-0.98]	4.4		2.9 [2.7-3.1]	4.9		8.4 [7.9-8.7]	6.3
Sr	0.75	0.78 [0.77-0.81]	1.7	2.5	2.7 [2.6-2.8]	3.5	7.5	8.4 [7.8-8.9]	4.0
		0.81 [0.79-0.83]	4.6		2.8 [2.7-2.9]	4.6		8.4 [8.3-8.6]	3.8
		0.81 [0.80-0.83]	2.2		2.8 [2.6-2.8]	3.6		8.1 [7.8-8.7]	3.9
Te	0.0038	0.0043 [0.0038-0.0047]	8.6	0.013	0.014 [0.013-0.016]	6.2	0.038	0.046 [0.038-0.047]	7.7
		0.0044 [0.0037-0.0045]	0.7		0.014 [0.013-0.015]	1.1		0.043 [0.037-0.045]	3.3
		0.0041 [0.0038-0.0049]	8.1		0.014 [0.013-0.015]	5.8		0.042 [0.041-0.045]	7.3
Th	0.00075	0.00081 [0.00077-0.00085]	2.9	0.0025	0.0029 [0.0025-0.0029]	5.4	0.0075	0.0078 [0.0077-0.0078]	3.6
		0.00074 [0.00073-0.00076]	14.3		0.0027 [0.0026-0.0027]	8.8		0.0080 [0.0075-0.0086]	5.3
		0.00073 [0.0007-0.00076]	5.6		0.0026 [0.0024-0.0028]	5.9		0.0076 [0.0075-0.0082]	3.9
Ti	0.75	0.74 [0.73-0.75]	2.0	2.5	2.5 [2.4-2.6]	3.0	7.5	7.3 [7.2-7.4]	3.5
		0.74 [0.73-0.76]	3.2		2.5 [2.4-2.5]	5.0		7.3 [6.8-7.8]	2.8
		0.72 [0.71-0.75]	2.1		2.4 [2.3-2.5]	3.3		7.4 [7.4-7.6]	3.4
Tl	0.0038	0.0038 [0.0036-0.0040]	3.4	0.013	0.013 [0.013-0.014]	3.8	0.038	0.042 [0.040-0.045]	4.3
		0.0043 [0.0042-0.0043]	15		0.015 [0.013-0.015]	9.1		0.043 [0.042-0.044]	2.8
		0.0042 [0.0039-0.0044]	6.2		0.014 [0.014-0.015]	4.8		0.043 [0.039-0.045]	4.1
U	0.000075	0.000073 [0.000066-0.000079]	6.5	0.00025	0.00027 [0.00027-0.00031]	5.2	0.00075	0.00078 [0.00073-0.00082]	3.8
		0.000070 [0.000066-0.000072]	9.9		0.00026 [0.00025-0.00028]	12.3		0.00078 [0.00078-0.00080]	11.8
		0.000076 [0.000068-0.000085]	7.0		0.00026 [0.00025-0.00027]	6.4		0.00085 [0.00081-0.00089]	5.4
V	0.11	0.12 [0.12-0.13]	4.1	0.38	0.38 [0.37-0.43]	4.2	1.1	1.2 [1.1-1.2]	4.2
		0.13 [0.12-0.13]	6.3		0.40 [0.39-0.41]	3.9		1.2 [1.1-1.3]	6.3
		0.13 [0.12-0.13]	4.4		0.41 [0.39-0.42]	4.2		1.1 [1.1-1.2]	4.5
W	0.075	0.078 [0.076-0.079]	1.6	0.25	0.26 [0.25-0.27]	2.1	0.75	0.71 [0.71-0.72]	3.2
		0.076 [0.075-0.078]	4.9		0.25 [0.24-0.25]	7.8		0.73 [0.68-0.76]	7.5
		0.075 [0.073-0.076]	2.2		0.25 [0.24-0.25]	3.3		0.76 [0.74-0.79]	3.9

ICP-MS method for human samples

Zn	15.0	13.6 [13.0-13.9]	2.3	50	47 [46-50]	3.1	150	144 [132-153]	4.4
		15.0 [14.7-15.6]	14.8		48 [48-51]	3.4		147 [137-153]	5.9
		15.0 [14.5-15.2]	5.5		48 [46-50]	3.2		147 [145-155]	4.6
Zr	0.0075	0.0085 [0.0079-0.0090]	10.0	0.025	0.038 [0.037-0.04]	3.3	0.075	0.076 [0.07-0.079]	7.0
		0.0091 [0.0071-0.0097]	1.7		0.038 [0.038-0.041]	2.0		0.078 [0.069-0.085]	8.6
		0.0090 [0.0075-0.0093]	9.4		0.039 [0.036-0.04]	3.2		0.080 [0.076-0.086]	7.2

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10. FIGURE LEGENDS

Figure 1: Concentrations of elements in (A) whole blood (μM), (B) hair ($\mu\text{mol/g}$) and (C) lung tissue ($\mu\text{mol/g}$) samples from 25 participants in a lung cancer clinical trial. The whiskers indicate the range of values, and the horizontal line indicates the mean.



