ACHIEVING CONSISTENCY IN SAMPLE PREPARATION TO ENSURE LOW BLANK LEVELS IN TRACE METAL DETERMINATION

In recent decades, significant strides have been made in enhancing the productivity, quality, and safety of the sample preparation processes, particularly focusing on the digestion step to improve efficiency. However, certain aspects of the sample preparation workflow still possess room for improvement, such as acid supply, reagent addition, vessel handling, and cleaning. In this study, we will explore how the implementation of Milestone easyFILL, an automated dosing system, can effectively overcome safety concerns and ensures consistency of result in sample preparation workflow for trace metal determination.

INTRODUCTION

In recent years, various industries have been inclined towards reducing their detection limits, as is evident in the recent FDA proposal of a “close to zero” plan to eradicate trace metal contaminants from baby food.[1] Reducing detection limits presents some challenges and laboratories need to have specific protocols and the right set-up to control possible contamination and ensure a robust approach. Among other parameters, the handling of the reagents, even if ultrapure, is a key factor in achieving lower detection limits and ensuring reliable quantification limits. Certainly, the quality of the acid plays a key role, but if not combined with proper handling, the reagent can easily be contaminated, affecting the blank values.

Any sample preparation for elemental analysis requires the addition of reagents. When working at trace levels, the choice falls on ultrapure acids. However, the presence of the analysts in routine operations could contaminate the acid and the sample, as well as could lead to inconsistent results. In fact, human skin, hair and sweat contain contaminants such as Zn, Cd, Pb, Fe, Cu, Ni, Mn and Na. In addition, the use of cosmetics and the presence of watches, rings, bracelets, etc. further increases the risk of contamination during handling. Even the routine use of pipettes can be a source of contamination when working at trace levels, either due to the presence of metal components in the pipettes or simply due to contamination on the tips. On top of this, there is human error. As reported by Rodushkin Et. Al,[2] the level of contaminants could raises from 5 to 35 times, moving from 74 ng/L to 368 – 2,627 ng/L. Those data demonstrate how easily a bottle of reagent lose its purity and gets contaminated in regular operations.

In this study we will focus on understanding how easyFILL, an automated dosing station, helps to control blanks in elemental analysis in term of reduced risk of contamination and consistency.

EXPERIMENTAL

INSTRUMENT AND REAGENTS

- Milestone's easyFILL
- Bottle-top dispenser
- ICP-MS/TQ
- UltraPure water
- HNO_3 (Trace Metal Grade)
- HCl (Trace Metal Grade)
- H_2O_2 (Analytical reagent grade)

Figure 1 – Milestone's easyFILL

The easyFILL is an automated dosing station specifically design to be integrated into the sample preparation process. In fact, it enables direct addition of concentrated acid in most digestion vessels and vials, without exposing the operator to the reagents. Through a dedicated user interface, the technician simply selects the type and volume of acids and then the system begins the addition. easyFILL is equipped with 6 lines for different reagents that through a peristaltic pump are directly loaded into digestion vessels and vials. For routine operations, the user has only to select a method and press "Start" to begin with the addition. Operator can create customized methods by choosing the volume of reagents, the type of reagents and even selecting a different chemistry for each position.

PROCEDURE

In both bottle-top dispenser and easyFILL procedures, reagentes were directly added into a 50mL falcon tube then directly analyzed in ICP-MS TQ.

ICP-MS TQ PARAMETERS

Spray Chamber Temperature	2.7°C
PeriPump Speed	15 rpm
Cool Flow	14 L/min
Auxiliary flow	0.8 L/min
Sampling Depth	5 mm
Plasma Power	1550 W
Nebulizer flow	1.09 L/min
Extraction lens	–184V
KED Flow	4.4 L/min
O_2 Flow	0.32 L/min
Dwell time	0.1 sec
Number of sweeps	10
Main runs	3
Runs/Sample	3

Table 1 – ICP-MS TQ parameters

Indium was used as internal (to check and correct any drift due to matrix effect

RESULTS AND DISCUSSION

In this study, we compared two different procedures for adding reagents: the conventional method using a bottle-top dispenser (manual addition) and the automated method using Milestone's easyFILL.
For this purpose, the most common reagents used in food testing laboratory such as UltraPure water, Trace Metal Grade nitric and chloridic acids, and Analytical grade hydrogen peroxide were analyzed in the blank tests. The analysis was performed with ICP-MS TQ on 67 elements representing both the major and the trace elements analysed in food matrices.
Tables 3 to 6 report the major elements while Tables 7 to 10 report trace elements.
For each element analysed, a comparison is made between the bottle-top dispenser and easyFILL, with the bias reported for evaluating differences between the two procedures.

A color code has been used to enhance the visual display of the bias values.

Result	Bias	Color code
Lower blank achieved with easyFILL	<0.00%	green
Same results	0.01-10.00%	black
Lower blank achieved with Bottle-top dispenser	>10.01	orange

Table 2 – Bias color code

In order to assess the consistency of the blank values over time, the above tests were carried out on an easyFILL that has been in regular use for 12 months. The same measurements were performed also on a brand new easyFILL and no significant differences was reported (for easier reading of the data, only the data obtained on the used system were reported in this document).

MAJOR ELEMENTS (µg/L)

ULTRAPURE WATER			
Element	**Manual Addition (µg/L)**	**EasyFILL addition (µg/L)**	**Bias (%)**
11B	0.08	0.01	-88
23Na	0.26	0.18	-31
24Mg	0.26	0.11	-58
27Al	0.15	0.14	-1
29Si	10.24	10.10	-1.3
31P	0.61	0.55	-9.0
32S	0.18	0.15	-17
39K	6.79	6.81	0.4
44Ca	0.08	0.05	-31
For both manual and easyFILL addition. 50 mL Falcon tube was filled with UltraPure water			

Table 3 –Major elements analyzed in UltraPure water (n=3).

HNO_3			
Element	**Manual Addition (µg/L)**	**EasyFILL addition (µg/L)**	**Bias (%)**
11B	0.23	0.22	-3
23Na	1.52	1.08	-29
24Mg	0.10	0.06	-36
27Al	0.15	0.04	-76
29Si	9.60	10.01	4
31P	0.47	0.37	-21
32S	0.21	0.12	-44
39K	6.75	6.37	-6
44Ca	0.35	0.15	-57
For both manual and easyFILL addition. 50 mL Falcon tube was filled with HNO_3 10% (5 mL TraceMetal HNO_3 conc + 45 mL UltraPure water)			

Table 4 –Major elements analyzed in HNO_3 (10%) (n=3).

HCl			
Element	**Manual Addition (µg/L)**	**EasyFILL addition (µg/L)**	**Bias (%)**
11B	0.54	0.32	-41
23Na	3.85	3.20	-17
24Mg	0.39	0.24	-37
27Al	0.13	0.11	-21
29Si	29.65	23.45	-21
31P	0.37	0.35	-4
32S	5.77	5.12	-11
39K	10.65	10.12	-5
44Ca	0.82	0.54	-34
For both manual and easyFILL addition. 50 mL Falcon tube was filled with HCl 10% (5 mL TraceMetal HCl conc + 45 mL UltraPure water)			

Table 5 –Major elements analyzed in HCl (10%) (n=3).

H_2O_2			
Element	**Manual Addition (µg/L)**	**EasyFILL addition (µg/L)**	**Bias (%)**
11B	3.16	2.41	-24
23Na	3.09	2.30	-26
24Mg	1.53	0.32	-79
27Al	2.00	0.10	-95
29Si	10.88	9.88	-9
31P	0.41	0.50	22
32S	4.96	3.47	-30
39K	4.57	1.52	-67
44Ca	1.28	0.45	-65
For both manual and easyFILL addition. 50 mL Falcon tube was filled with H_2O_2 (10%) (5 mL H_2O_2 Analytical grade conc + 45 mL UltraPure water)			

Table 6 –Major elements analyzed in H_2O_2 (10%) (n=3).

easyFILL demonstrates better acid dispensing capability and a superior blank value for all major elements, as indicated by color codes, compared to the bottle-top dispensing procedure. The addition of easyFILL resulted in a higher bias only when analyzing 31P in H_2O_2 (30%), but the concentration is not significant for food analysis.

TRACE ELEMENTS (ng/L)

ULTRAPURE WATER											
Element	**Manual Addition (ng/L)**	**EasyFILL addition (ng/L)**	**Bias (%)**	**Element**	**Manual Addition (ng/L)**	**EasyFILL addition (ng/L)**	**Bias (%)**	**Element**	**Manual Addition (ng/L)**	**EasyFILL addition (ng/L)**	**Bias (%)**
7Li	0.00	0.00	-	**93Nb**	0.00	0.00	-	**163Dy**	0.00	0.00	-
9Be	2.94	2.32	-21	**98Mo**	5.42	0.78	-86	**165Ho**	0.00	0.00	-
45Sc	0.00	0.00	-	**101Ru**	0.70	0.17	-75	**166Er**	0.00	0.00	-
48Ti	0.00	0.00	-	**103Rh**	0.00	0.00	-	**169Tm**	0.00	0.00	-
51V	0.00	0.00	-	**105Pd**	0.00	0.00	-	**172Yb**	0.00	0.00	-
52Cr	0.00	0.00	-	**107Ag**	0.00	0.00	-	**175Lu**	0.00	0.00	-
55Mn	17.54	6.30	-64	**111Cd**	0.00	0.00	-	**178Hf**	0.00	0.00	-
56Fe	0.00	0.00	-	**118Sn**	0.00	0.00	-	**181Ta**	0.00	0.00	-
59Co	0.29	0.00	-100	**121Sb**	0.00	0.00	-	**182W**	2.30	1.93	-16
60Ni	0.00	0.00	-	**125Te**	0.00	0.00	-	**185Re**	0.01	0.00	-58
63Cu	0.00	0.00	-	**133Cs**	0.05	0.00	-100	**193Ir**	49.28	23.50	-52
66Zn	0.00	0.00	-	**138Ba**	0.00	0.00	-	**195Pt**	2.34	1.46	-38
71Ga	0.00	0.00	-	**139La**	0.00	0.00	-	**197Au**	0.00	0.00	-

73Ge	0.00	0.00	-	**140Ce**	0.00	0.00	-	**202Hg**	4.29	0.30	-93
75As	0.33	0.00	-100	**141Pr**	0.00	0.00	-	**205Tl**	0.19	0.05	-75
80Se	1.30	0.18	-86	**144Nd**	0.00	0.00	-	**208Pb**	0.00	0.00	-
85Rb	0.79	0.00	-100	**149Sm**	0.03	0.00	-100	**232Th**	0.00	0.00	-
88Sr	0.62	0.00	-100	**153Eu**	0.00	0.00	-	**238U**	0.00	0.00	-
89Y	0.00	0.00	-	**157Gd**	0.00	0.00	-				
90Zr	0.00	0.00	-	**159Tb**	0.00	0.00	-				
For both manual and easyFILL addition. 50 mL Falcon tube was filled with UltraPure water											

Table 7 –Trace elements analyzed in UltraPure water (n=3).

HNO_3											
Element	**Manual Addition (ng/L)**	**EasyFILL addition (ng/L)**	**Bias (%)**	**Element**	**Manual Addition (ng/L)**	**EasyFILL addition (ng/L)**	**Bias (%)**	**Element**	**Manual Addition (ng/L)**	**EasyFILL addition (ng/L)**	**Bias (%)**
7Li	0.00	0.00	-	**93Nb**	0.00	0.00	-	**163Dy**	0.01	0.00	-17
9Be	0.00	0.00	-	**98Mo**	0.00	0.00	-	**165Ho**	0.00	0.00	-
45Sc	0.00	0.00	-	**101Ru**	0.23	0.13	-42	**166Er**	0.00	0.00	-
48Ti	0.89	0.00	-100	**103Rh**	1.57	1.22	-22	**169Tm**	0.00	0.00	-
51V	0.00	0.00	-	**105Pd**	1.78	3.04	3.04	**172Yb**	0.00	0.00	-
52Cr	0.00	0.00	-	**107Ag**	0.00	0.00	-	**175Lu**	0.00	0.00	-
55Mn	60.33	52.45	-13	**111Cd**	0.04	0.00	-100	**178Hf**	1.07	0.37	-66
56Fe	480.42	419.10	-13	**118Sn**	0.00	0.00	-	**181Ta**	0.00	0.00	-
59Co	7.37	4.77	-35	**121Sb**	0.00	0.00	-	**182W**	8.79	8.79	0
60Ni	6.71	4.43	-34	**125Te**	0.06	0.00	-98	**185Re**	0.01	0.00	-67
63Cu	8.56	6.07	-29	**133Cs**	0.00	0.00	-	**193Ir**	44.46	31.28	-30
66Zn	0.00	0.00	-	**138Ba**	22.26	19.06	-14	**195Pt**	3.02	2.60	-14
71Ga	0.00	0.00	-	**139La**	0.10	0.07	-26	**197Au**	0.00	0.00	-
73Ge	0.00	0.00	-	**140Ce**	0.13	0.14	7	**202Hg**	0.73	0.00	-100
75As	0.11	0.00	-100	**141Pr**	0.00	0.00	-	**205Tl**	0.17	0.07	-60
80Se	0.00	0.00	-	**144Nd**	0.03	0.04	13	**208Pb**	0.00	3.55	3.45
85Rb	0.00	0.00	-	**149Sm**	0.03	0.02	-42	**232Th**	0.17	0.03	-81
88Sr	17.66	14.90	-16	**153Eu**	0.01	0.00	-55	**238U**	0.01	0.01	0
89Y	0.01	0.02	16	**157Gd**	0.06	0.04	-34				
90Zr	1.25	0.95	-24	**159Tb**	0.00	0.00	-26				
For both manual and easyFILL addition. 50 mL Falcon tube was filled with HNO_3 10% (5 mL TraceMetal HNO_3 conc + 45 mL UltraPure water											

Table 8 –Trace elements analyzed in HNO_3 (10%) (n=3).

HCl											
Element	Manual Addition (ng/L)	EasyFILL addition (ng/L)	Bias (%)	Element	Manual Addition (ng/L)	EasyFILL addition (ng/L)	Bias (%)	Element	Manual Addition (ng/L)	EasyFILL addition (ng/L)	Bias (%)
7Li	2.68	0.23	-91	**93Nb**	0.00	0.00	-	**163Dy**	0.05	0.06	7
9Be	1.44	0.75	-48	**98Mo**	0.00	0.00	-	**165Ho**	0.00	0.00	-
45Sc	0.28	0.26	-7	**101Ru**	0.00	0.00	-	**166Er**	0.02	0.02	0
48Ti	19.38	17.92	-8	**103Rh**	0.08	0.03	-61	**169Tm**	0.00	0.00	-
51V	411.05	449.71	9	**105Pd**	1.90	0.49	-74	**172Yb**	0.02	0.02	0
52Cr	136.53	133.94	-2	**107Ag**	0.26	0.08	-68	**175Lu**	0.00	0.00	-
55Mn	54.86	44.91	-18	**111Cd**	0.34	0.28	-18	**178Hf**	0.05	0.00	-98
56Fe	1303	1202	-8	**118Sn**	30.14	25.77	-14	**181Ta**	0.00	0.00	-
59Co	5.24	4.15	-21	**121Sb**	2.49	0.00	-100	**182W**	6.29	6.12	-3
60Ni	345.01	331.11	-4	**125Te**	0.00	0.29	291	**185Re**	0.09	0.03	-64
63Cu	11877	11688	-2	**133Cs**	0.16	0.01	-95	**193Ir**	0.07	0.04	-39
66Zn	465.36	155.20	-67	**138Ba**	30.17	26.25	-13	**195Pt**	0.31	0.23	-26
71Ga	9.30	5.88	-37	**139La**	0.23	0.22	-5	**197Au**	8.88	6.40	-28
73Ge	1749	1632	-7	**140Ce**	0.23	0.25	7	**202Hg**	3.88	0.50	-87
75As	7.05	5.17	-27	**141Pr**	0.04	0.01	-61	**205Tl**	0.00	0.00	-
80Se	10.50	8.11	-23	**144Nd**	0.22	0.20	-8	**208Pb**	3.34	3.34	0
85Rb	4.28	3.55	-17	**149Sm**	0.10	0.03	-67	**232Th**	0.04	0.03	-39
88Sr	18.29	13.54	-26	**153Eu**	0.01	0.01	-26	**238U**	0.01	0.01	0
89Y	0.13	0.11	-11	**157Gd**	0.04	0.03	-39				
90Zr	3.65	2.68	-27	**159Tb**	0.00	0.00	-				
For both manual and easyFILL addition. 50 mL Falcon tube was filled with HCl 10% (5 mL TraceMetal HCl conc + 45 mL UltraPure water)											

Table 9 –Trace elements analyzed in HCl (10%) (n=3).

H_2O_2											
Element	Manual Addition (ng/L)	EasyFILL addition (ng/L)	Bias (%)	Element	Manual Addition (ng/L)	EasyFILL addition (ng/L)	Bias (%)	Element	Manual Addition (ng/L)	EasyFILL addition (ng/L)	Bias (%)
7Li	0.00	0.00	0	**93Nb**	248.71	127.91	-49	**163Dy**	0.00	0.00	-
9Be	2.94	1.20	-59	**98Mo**	47.52	32.47	-32	**165Ho**	0.00	0.00	-
45Sc	0.14	0.01	-92	**101Ru**	25.60	15.01	-41	**166Er**	0.01	0.00	-82
48Ti	48.59	33.80	-30	**103Rh**	0.00	0.00	-	**169Tm**	0.00	0.00	-
51V	0.00	0.00	-	**105Pd**	0.00	0.00	-	**172Yb**	0.01	0.00	-51
52Cr	32.33	17.91	-45	**107Ag**	0.00	0.00	-	**175Lu**	0.00	0.00	-
55Mn	37.17	0.00	-100	**111Cd**	0.59	0.29	-51	**178Hf**	0.00	0.00	-

56Fe	327.73	61.06	-81	**118Sn**	0.00	0.00	-	**181Ta**	867.18	584.63	-33
59Co	44.84	2.43	-95	**121Sb**	0.00	0.00	-	**182W**	15.60	10.36	-34
60Ni	54.31	4.90	-91	**125Te**	0.30	0.00	-100	**185Re**	0.00	0.00	-
63Cu	238.70	26.33	-89	**133Cs**	0.16	0.00	-99	**193Ir**	0.00	0.00	-
66Zn	2805.80	239.75	-91	**138Ba**	388.81	270.49	-30	**195Pt**	1.94	1.54	-21
71Ga	0.00	0.00	-	**139La**	0.09	0.01	-86	**197Au**	11.55	7.17	-38
73Ge	0.84	0.00	-100	**140Ce**	0.00	0.00	-	**202Hg**	0.80	0.47	-41
75As	0.18	0.00	-99	**141Pr**	0.00	0.00	-	**205Tl**	0.00	0.00	-
80Se	0.61	0.48	-21	**144Nd**	0.00	0.00	-	**208Pb**	2.91	0.19	-94
85Rb	4.12	0.73	-82	**149Sm**	0.00	0.02	>100	**232Th**	0.00	0.00	-
88Sr	56.74	11.08	-80	**153Eu**	0.02	0.02	0	**238U**	0.00	0.00	-
89Y	0.00	0.00	-	**157Gd**	0.00	0.00	-				
90Zr	1.19	0.00	-100	**159Tb**	0.00	0.00	-				

For both manual and easyFILL addition. 50 mL Falcon tube was filled with H_2O_2 (10%) (5 mL H_2O_2 Analytical grade conc + 45 mL UltraPure water)

Table 10 –Trace elements analyzed in H_2O_2 (10%) (n=3).

As well as for Major elements and even for Trace elements easyFILL demonstrated better acid dispensing capability and a superior blank value compared to the bottle-top dispensing procedure. As indicated by color codes, there were some sporadic values where easyFILL bias were higher than the conventional dispenesing procedure but even in these cases the concentrationdifferences were not significant for food analysis.

The assessment of the consistency of the blank values over time was proved by measuring values on an easyFILL in regular use for 12 months.

The use of easyFILL completely removes the potential source of contamination associated with reagent handling and dosing whilst reduces human error and contamination coming from the analyst. The data showed how easyFILL is a true asset to any laboratory performing trace element analysis.

CONCLUSIONS

The data shown demonstrates the ability to integrate easyFILL into trace elemental analysis by ensuring low blanks. The metal-free lines avoid any exposure of the reagents to metals, while the automation eliminates human error, the possible analyst contamination.

REFERENCES

1. *FDA, The Baby Food Safety Act of 2021*
2. *I. Rodushkin, E. Engström, D. C. Baxter Anal. Bioanal. Chem. 396 (2010) 365-377.*