CT Associates, Inc.
7121 Shady Oak Road, Eden Prairie, MN 55344-3516
Telephone: (952) 470-0166 Fax: (952) 942-0293
Website: http://www.ctassociatesinc.com

Trace Metal Dynamic Extraction from Three Centrifugal Pumps in Hydrochloric Acid

Submitted to:

Juergen Hahn
Levitronix GmbH

Submitted by:

Mark Litchy
CT Associates, Inc.

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Summary

The objective of this test was to determine the type and rate of trace metals extraction from three pumps: Levitronix BPS-4000 (S/N: NA), Iwaki magnetic drive pump (model #: MDM-1518PKK07, serial #: 1011162190), and an Innovative Mag-Drive (Innomag) pump (model #: U-MAG.U1, code: U11561102-UDO, serial #: 16423). A dynamic extraction test method was used in 35% hydrochloric (HCl) acid during the 10-day extraction test. Both surface and bulk contamination can be determined with this method. Surface contamination is defined as the amount of contamination extracted in the first 40 minutes of exposure of the component to chemical. Bulk contamination is defined as the amount of contamination extracted after 40 minutes of exposure to chemical.

The pumps were plumbed into the dynamic extraction test apparatus shown in Figure 1. High purity 35% HCl was used as the extractant during each test. Continuous flow of the chemical was maintained through the pumps during each test. The test pumps were operated continuously during the test to ensure that the acid was well mixed within the pump. A background sample was taken from each test system prior to each test and samples were taken at approximately evenly spaced time intervals on a logarithmic scale from a sample port located in the circulation loop. The chemical samples were submitted for analysis of 38 metallic elements. The results of the analyses were converted to cumulative mass extracted.

The surface contamination extracted from all elements was 0.9, 869, and 875 μg for the Levitronix, Iwaki, and Innomag pumps, respectively. The surface contamination measured from the Iwaki and Innomag pumps was approximately 1,000 times higher than measured from the Levitronix pump. The mass extraction rates were calculated to be 0.11, 11.2, and 10.1 μg/day at 7 days for the Levitronix, Iwaki, and Innomag pumps, respectively. Thus, the mass extraction rates from the Iwaki and Innomag pumps were approximately 100 times higher than from the Levitronix pump. The total contamination from all elements extracted during the tests was 3.8, 1257, and 1391 μg for the Levitronix, Iwaki, and Innomag pumps, respectively.

Test System

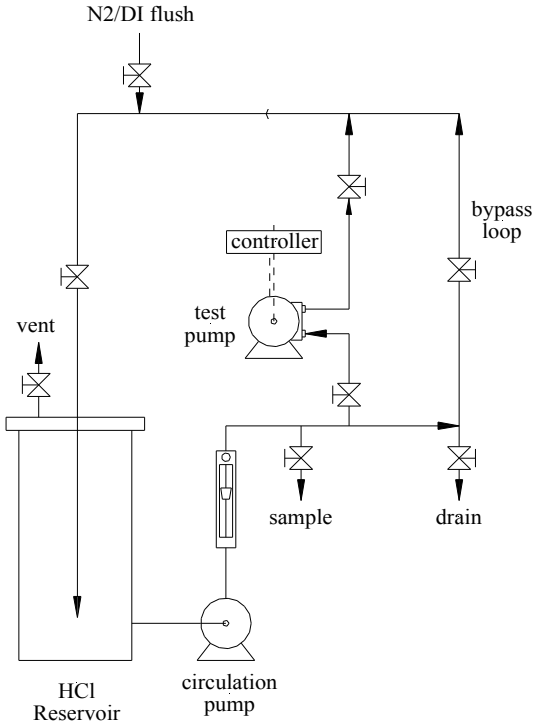
The dynamic extraction test system is shown in Figure 1. Except for the chemical reservoir, all of the wetted system components are made of fluoropolymers. The reservoir is constructed of high-density polyethylene. All of the components in the extraction test system were preconditioned for a minimum of two months in 35% HCl, except for the PFA flanges and PTFE flange gaskets that were used to connect to the test pump. These fittings were preconditioned for a three-week period prior to the test.

System Cleaning

Prior to testing, the system shown was cleaned with a 10% hydrochloric acid solution, with fluoropolymer spool pieces in place of each pump. The spool pieces allow the system to be cleaned with the plumbing pieces required for the test, without having the test pump in the system. The purpose of cleaning the system was to remove any contamination remaining in the system from the previous test, and to clean the components that were installed to connect to the

test pump. After cleaning, the system was flushed with ultra pure water and drained completely three times.

Figure 1. Schematic of Dynamic Extraction Test System



Extraction Test Procedure

Prior to the test, each pump was flushed with approximately 70 L of ultra pure water.

After the system was cleaned, one of the test pumps was installed into the system, but was isolated by closing isolation valves located on both sides of the pump. A known volume of 35% Fisher Scientific Trace Metal Grade hydrochloric acid was added to the reservoir. To maximize the sensitivity of the test, the volume of hydrochloric acid was minimized. The initial volume included enough chemical to fill the system plumbing and test pump plus an additional 1000 mL for chemical samples. The acid was added to the system one day prior to the start of the test and was circulated using a pre-extracted circulation pump shown in Figure 1. A background sample of this chemical was taken just prior to initiating circulation of the chemical through each test pump. Five additional samples of chemical were removed from the system during 10 days of circulation through each pump. Continuous flow of the chemical was maintained through each pump during the test at a low flow rate. Each test pump was continuously operated during the test at a low speed. The sample times were approximately evenly spaced on a logarithmic scale (see Table I) to improve the accuracy of the data analysis. After the 10-day sample was taken, the samples were submitted as a group to Seastar Chemicals, Inc. (Sidney, BC, Canada) for the trace metals analysis of 38 elements using ICP-MS (inductively coupled plasma-mass spectroscopy). The detection limits for all elements are presented in Appendix A. Finally, the system was flushed with water and the pump was removed.

Miscellaneous Test Specifics

Specifics to these tests are shown in Table I.

Table I. Test specifics

Test Conditions	
Component(s) Tested	Levitronix BPS-4000 (S/N: NA), Iwaki magnetic drive pump (model #: MDM-1518PKK07, serial #: 1011162190), and a Innovative Mag-Drive (Innomag) pump (model #: U-MAG.U1, code: U11561102-UDO, serial #: 16423).
Chemical Manufacturer and Grade	Fisher Scientific – Trace Metal Grade
Chemical Volume	2645 mL (Levitronix), 3072 mL (Iwaki), 2722 mL (Innomag)
Temperature	21-23 °C
Sample Times	Background, 40 minutes, 2 hours, 8 hours, 2 days, 10 days

Results

Surface contamination

Table II shows the major contributors to surface contamination in each test. The raw data are found in Appendix A. Iron was either highest or second highest surface contaminant in all three tests. In the Levitronix test, iron, aluminum and calcium accounted for more than 75% of the surface contamination. In the Iwaki test, sodium and iron accounted for nearly 70% of the surface contamination; while in the Innomag test, iron alone accounted for more than 60% of the surface contamination. A variety of other elements contributed the remainder of the surface contamination in each test. The surface contamination extracted from all elements was 0.9, 869, and 875 μg for the Levitronix, Iwaki, and Innomag pumps, respectively.

Table II. Surface contamination (μg) measured during test

BPS-4000			Iwaki			Innomag		
Element	Mass Extracted (ug)	% of Total (%)	Element	Mass Extracted (ug)	% of Total (%)	Element	Mass Extracted (ug)	% of Total (%)
Fe	0.35	39.8	Na	371.5	42.7	Fe	534.4	61.0
Al	0.17	19.3	Fe	234.9	27.0	Bi	59.6	6.8
Ca	0.15	17.0	K	97.5	11.2	Ca	45.8	5.2
Cu	0.07	8.0	Ca	52.1	6.0	Cu	40.9	4.7
Na	0.07	8.0	Zn	20.8	2.4	Al	39.4	4.5
Mg	0.05	5.7	Mg	15.7	1.8	Sn	23.9	2.7
Misc.	0.02	2.3	Ti	14.7	1.7	Zn	23.9	2.7
			Cu	12.8	1.5	Ni	23.8	2.7
			Misc.	49.3	5.7	Misc.	83.7	9.6
Total	**0.88**	**100.0**	**Total**	**869.3**	**100.0**	**Total**	**875.4**	**100.0**

Bulk contamination

Figures 2-4 show the mass of selected elements extracted from the bulk material of the pumps over time. The data are plotted on a log-log scale as a function of time. All figures exclude surface contamination.

Like the surface contamination, a variety of elements contributed to the bulk contamination during each test. In the Levitronix test, iron and aluminum accounted for nearly 50% of the bulk contamination. In the Iwaki test, sodium accounted for more than 50% of the bulk contamination; while in the Innomag test, bismuth, iron and tin accounted for more than 50% of the bulk contamination. A variety of other elements contributed the remainder of the bulk contamination in each test. The total bulk contamination from all elements extracted during the tests was 2.9, 388, and 516 μg for the Levitronix, Iwaki, and Innomag pumps, respectively.

Figure 5 presents the mass extracted from the bulk material of each pump over time for all measured elements on a log-log scale. Since theory predicts that the extraction data can be fit by a power law equation, the data should follow a straight line when plotted in this format [1]. A simple regression analysis of the data in this format is also presented in Figure 5.

Figure 2. Mass extracted for the primary contributing elements from the Levitronix pump

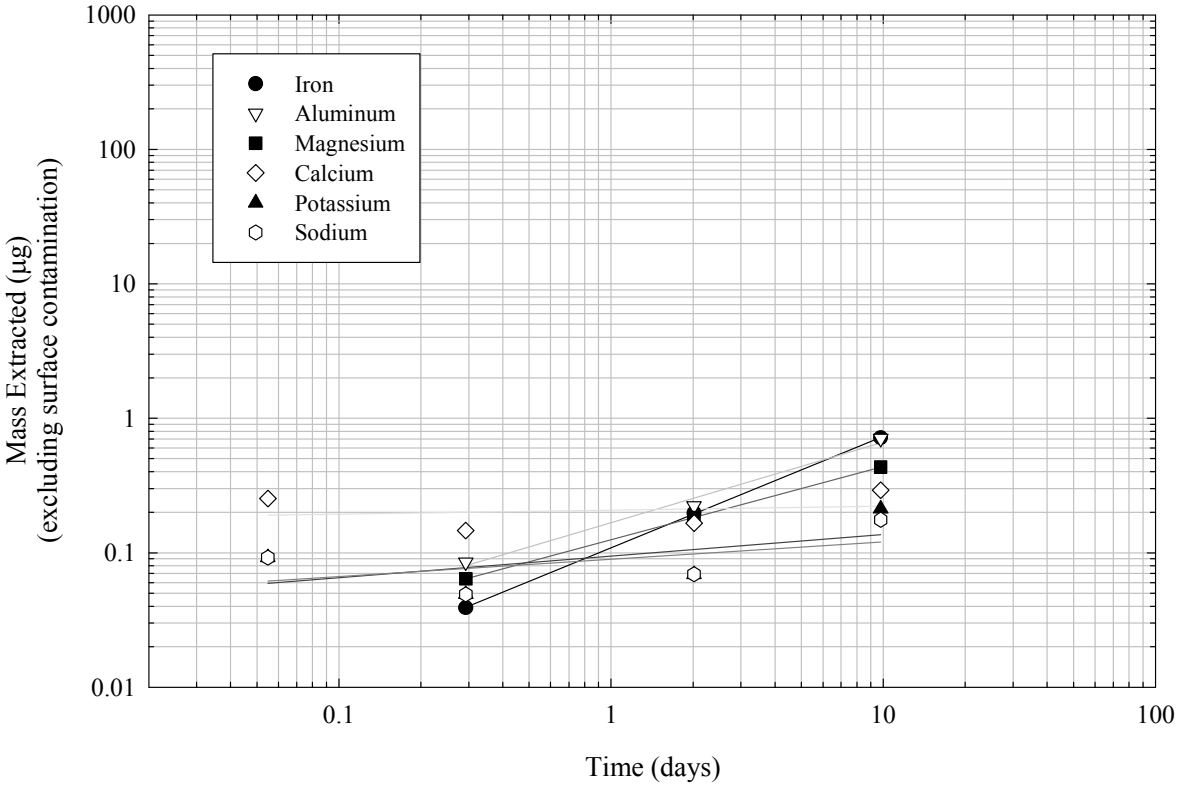


Figure 3. Mass extracted for the primary contributing elements from the Iwaki pump

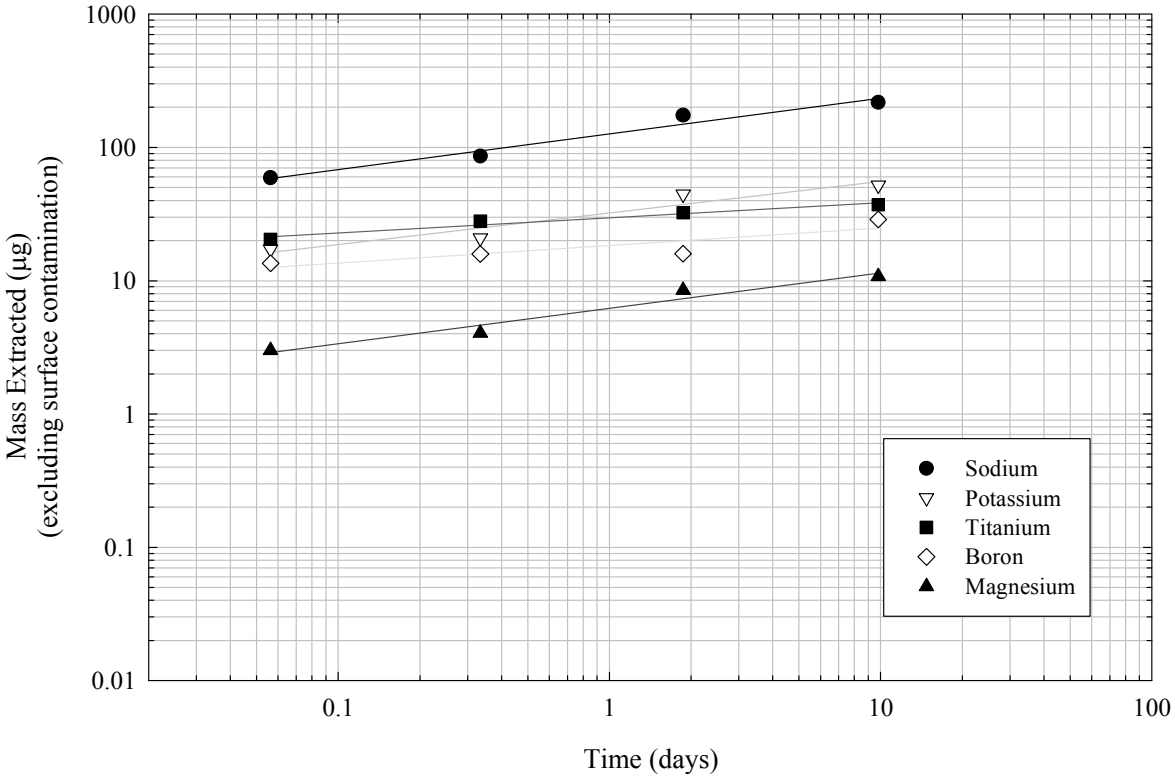


Figure 4. Mass extracted for the primary contributing elements from the Innomag pump

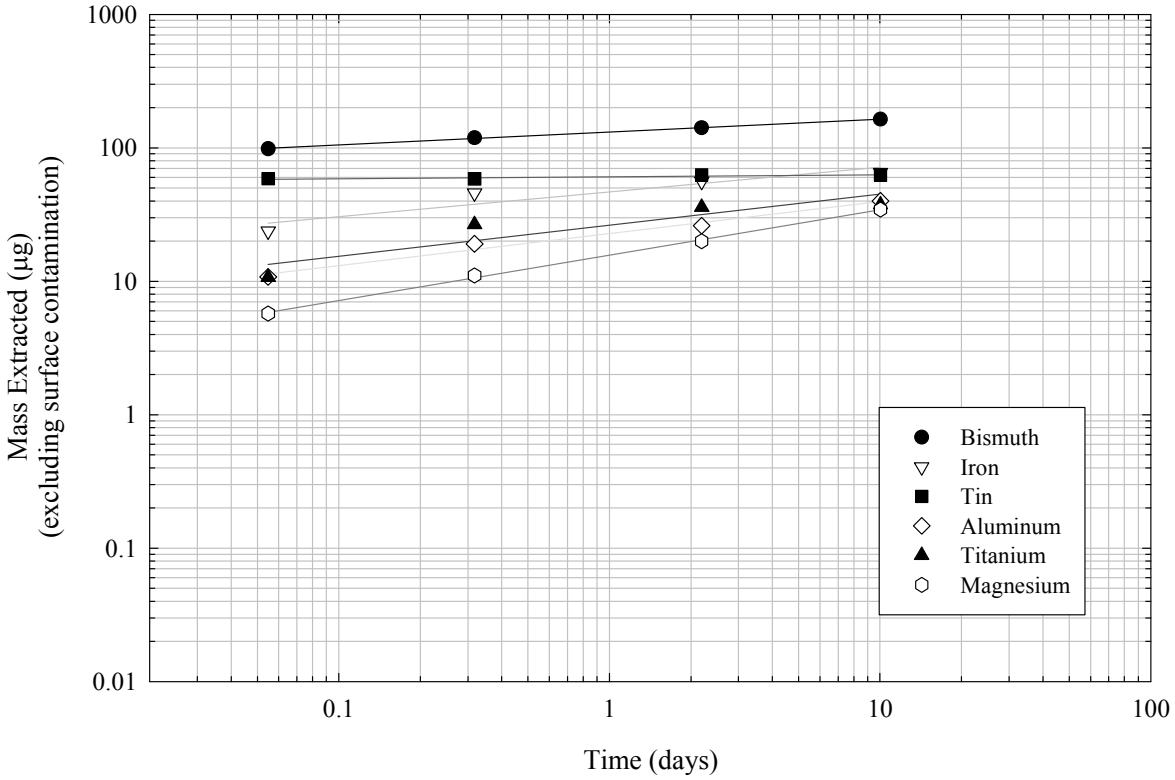
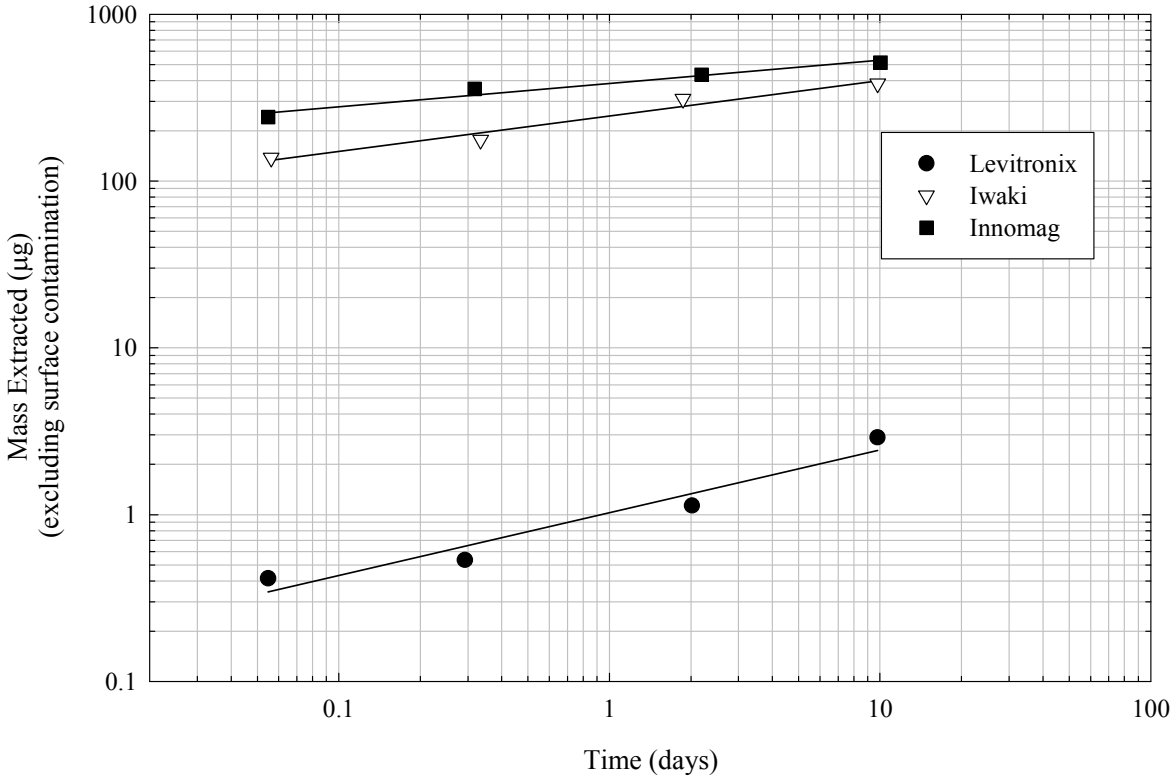


Figure 5. Total mass extracted from the Levitronix, Iwaki, and Innomag pumps



The mathematical model used to predict the cumulative mass extracted as a function of time is an equation of the type:

$$m=k*t^n \qquad (1)$$

where:

t = time (days)
m = cumulative mass extracted (µg) at time t
k = proportionality constant
n = exponent

Taking the log of both sides of the equation gives:

$$\log(m) = \log(k) + n*\log(t) \qquad (2)$$

The parameters in equation (1) for total metals are given in Table III. These values were obtained from the linear regression analysis illustrated in Figure 5, where n is the slope and log k is the intercept as shown in equation (2).

Table III. Mass extraction parameters

Pump	k	n
Levitronix	1.028	0.376
Iwaki	244.9	0.212
Innomag	383.7	0.140

The values for constants k and n can be used to calculate the total mass extracted from each pump at different times using equation (1). In addition, the rate of extraction can be determined by taking the derivative of equation (1) with respect to time:

$$\text{Rate of extraction} = dm/dt = n*k*t^{n-1} \qquad (3)$$

Based on equation (3) and the calculated curve fit parameters listed in Table III, the rates of extraction for total metals at 1, 7, and 14 days are shown in Table IV.

Table IV. Calculated rates of extraction for 37 metallic elements

	Extraction Rate (μg/day)		
Pump	1 day	7 days	14 days
Levitronix	0.39	0.11	0.07
Iwaki	51.9	11.2	6.5
Innomag	53.7	10.1	5.6

The mass extraction rates were calculated to be 0.11, 11.2, and 10.1 μg/day at 7 days for the Levitronix, Iwaki, and Innomag pumps, respectively. The total contamination from all elements extracted during the tests was 3.8, 1257, and 1391 μg for the Levitronix, Iwaki, and Innomag pumps, respectively.

Conclusions

Three pumps (Levitronix BPS-4000, Iwaki magnetic drive pump (model #: MDM-1518PKK07), and an Innovative Mag-Drive (Innomag) pump (model #: U-MAG.U1)) were tested for trace metal extraction using a dynamic extraction test method in 35% HCl. The surface contamination extracted from all elements was 0.9, 869, and 875 μg for the Levitronix, Iwaki, and Innomag pumps, respectively. The surface contamination measured from the Iwaki and Innomag pumps was approximately 1,000 times higher than measured from the Levitronix pump. The mass extraction rates were calculated to be 0.11, 11.2, and 10.1 μg/day at 7 days for the Levitronix, Iwaki, and Innomag pumps, respectively. Thus, the mass extraction rates from the Iwaki and Innomag pumps were approximately 100 times higher than from the Levitronix pump. The total bulk contamination from all elements extracted during the tests was 2.9, 388, and 516 μg for the Levitronix, Iwaki, and Innomag pumps, respectively.

References

Grant D.C., T. Lemke, G. Duepner, D. Wilkes, and N. Powell (1996). "Measurement of Inorganic Contaminant Extraction from Fluid Handling Components by Dynamic Extraction," *Journal of the Institute of Environmental Sciences* 39(2):29-37.

Appendix A

Dynamic Extraction Study - Test Results and Data Analysis

Test Material: BPS-4000 Serial Numbers:
Model No:

Leachate Type: 35% HCl
Initial Fill Volume: 2.645 liters
Sample+Rinse Volume 0: 0.170 liters
Sample+Rinse Volume 1: 0.172 liters
Sample+Rinse Volume 2: 0.167 liters
Sample+Rinse Volume 3: 0.170 liters
Sample+Rinse Volume 4: 0.176 liters

Date		02/22/11	02/22/11	02/22/11	02/22/11	02/24/11	03/04/11
Time		13:12	13:53	15:12	20:54	14:19	8:45
Time (hours)	Detection Limit	Control	0.00	1.32	7.02	48.43	234.87
			Concentration (ppb)				

	Day>>>		Cumulative Metal Extraction (ug)						
			0.055	0.292	2.018	9.786		Total	% of Total
	Surface	% of Surface	Extracted						
Ag	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Al	0.17	19.7%	0.00	0.09	0.22	0.7	24.3%	0.88	23.2%
As	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Au	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
B	-0.02	-2.8%	-0.02	-0.04	0.03	0.0	1.2%	0.01	0.3%
Ba	0.00	0.6%	0.00	0.01	0.01	0.0	1.2%	0.04	1.1%
Be	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Bi	0.00	-0.3%	0.00	0.00	0.00	0.0	0.1%	0.00	0.0%
Ca	0.15	16.9%	0.25	0.15	0.17	0.3	10.0%	0.44	11.6%
Cd	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Co	0.00	0.3%	0.00	0.00	0.00	0.0	0.0%	0.00	0.1%
Cr	0.02	2.8%	0.00	0.04	0.02	0.1	2.6%	0.10	2.7%
Cs	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Cu	0.07	8.4%	0.00	0.00	0.02	0.0	1.3%	0.11	3.0%
Fe	0.35	39.3%	-0.05	0.04	0.20	0.7	24.6%	1.06	28.0%
Ga	0.00	0.0%	0.00	0.00	0.00	0.0	0.1%	0.00	0.0%
In	0.00	0.0%	0.00	0.00	0.00	0.0	0.1%	0.00	0.0%
K	0.00	0.0%	0.09	0.05	0.07	0.2	7.3%	0.21	5.6%
Li	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Mg	0.05	5.6%	0.00	0.06	0.18	0.4	14.9%	0.48	12.7%
Mn	0.00	0.0%	0.00	0.00	0.00	0.0	0.1%	0.00	0.1%
Mo	0.00	0.0%	0.00	0.00	0.00	0.0	0.1%	0.00	0.1%
Na	0.07	8.4%	0.09	0.05	0.07	0.2	6.1%	0.25	6.6%
Nb	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Nd	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Ni	0.00	0.0%	0.00	0.02	0.02	0.0	1.4%	0.04	1.0%
Pb	0.01	0.8%	0.00	0.00	0.00	0.0	0.1%	0.01	0.2%
Rb	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Re	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Sn	-0.02	-2.8%	0.00	0.02	0.04	0.0	0.8%	0.00	0.0%
Sr	0.00	0.3%	0.00	0.00	0.00	0.0	0.1%	0.01	0.2%
Ti	0.00	0.0%	0.00	0.00	0.02	0.1	1.9%	0.06	1.5%
Tl	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
U	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
V	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
W	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Zn	0.02	2.8%	0.05	0.05	0.05	0.0	1.6%	0.07	1.9%
Zr	0.00	0.0%	0.00	0.00	0.00	0.0	0.1%	0.00	0.1%
Total	**0.88**		**0.41**	**0.53**	**1.13**	**2.91**		**3.79**	

Extraction Rates (ug/day)

				Day	
B0(=log K	0.012	K =	1.028016	1	0.39
B1(=n)	0.376	N=	0.376	7	0.11
		N-1 =	-0.624	14	0.07

Dynamic Extraction Study - Test Results and Data Analysis

Test Material: Iwaki Serial Numbers: 1011162190

Model No: MDM-1518PKK07

Leachate Type:	35% HCl
Initial Fill Volume:	3.072 liters
Sample+Rinse Volume 0:	0.304 liters
Sample+Rinse Volume 1:	0.176 liters
Sample+Rinse Volume 2:	0.162 liters
Sample+Rinse Volume 3:	0.160 liters
Sample+Rinse Volume 4:	0.161 liters

Date		12/21/10	12/21/10	12/21/10	12/21/10	12/23/10	12/31/10
Time		13:38	14:16	15:37	22:17	11:07	9:31
Time (hours)	Detection Limit	Control	0.00	1.35	8.02	44.85	235.25
			Concentration (ppb)				

	Day>>>		Cumulative Metal Extraction (ug)						
	Surface	% of Surface	0.056	0.334	1.869	9.802		Total	% of Total
			Extracted						
Ag	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Al	10.80	1.2%	1.89	2.21	4.93	7.0	1.8%	17.84	1.4%
As	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Au	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
B	9.72	1.1%	13.48	15.81	15.95	28.8	7.4%	38.55	3.1%
Ba	5.70	0.7%	2.31	2.43	3.40	4.2	1.1%	9.93	0.8%
Be	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Bi	0.02	0.0%	0.00	0.00	0.02	0.0	0.0%	0.05	0.0%
Ca	52.08	6.0%	4.51	3.76	5.44	4.3	1.1%	56.39	4.5%
Cd	0.02	0.0%	0.00	0.02	0.05	0.0	0.0%	0.07	0.0%
Co	0.77	0.1%	0.26	0.19	0.21	0.3	0.1%	1.02	0.1%
Cr	4.79	0.6%	2.72	2.31	2.60	2.0	0.5%	6.80	0.5%
Cs	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Cu	12.76	1.5%	2.31	1.92	4.82	5.4	1.4%	18.18	1.4%
Fe	234.91	27.0%	0.00	0.00	0.00	0.0	0.0%	234.91	18.7%
Ga	0.50	0.1%	0.21	0.23	0.50	0.6	0.1%	1.06	0.1%
In	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
K	97.51	11.2%	17.26	20.93	44.42	52.1	13.4%	149.60	11.9%
Li	0.02	0.0%	0.00	0.00	0.00	0.0	0.0%	0.02	0.0%
Mg	15.70	1.8%	3.01	4.05	8.50	10.8	2.8%	26.45	2.1%
Mn	2.33	0.3%	0.13	-0.16	0.04	0.2	0.1%	2.56	0.2%
Mo	0.35	0.0%	0.26	0.28	0.44	0.6	0.2%	0.94	0.1%
Na	371.50	42.7%	59.13	85.90	174.07	217.0	56.0%	588.47	46.8%
Nb	0.05	0.0%	0.08	0.08	0.10	0.1	0.0%	0.17	0.0%
Nd	0.44	0.1%	-0.03	-0.07	-0.03	0.0	0.0%	0.43	0.0%
Ni	4.98	0.6%	0.91	0.30	0.37	0.1	0.0%	5.06	0.4%
Pb	1.49	0.2%	0.08	-0.12	-0.14	-0.2	-0.1%	1.27	0.1%
Rb	0.02	0.0%	0.00	0.00	0.00	0.0	0.0%	0.05	0.0%
Re	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Sn	0.42	0.0%	0.05	0.83	1.33	1.6	0.4%	2.06	0.2%
Sr	0.44	0.1%	0.05	0.05	0.12	0.1	0.0%	0.56	0.0%
Ti	14.73	1.7%	20.43	28.01	32.30	37.1	9.6%	51.83	4.1%
Tl	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
U	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
V	3.96	0.5%	7.52	8.71	10.55	10.3	2.7%	14.29	1.1%
W	0.14	0.0%	0.10	0.10	0.15	0.2	0.1%	0.35	0.0%
Zn	20.79	2.4%	0.78	-1.55	0.10	0.3	0.1%	21.08	1.7%
Zr	2.35	0.3%	2.28	2.55	3.52	4.4	1.1%	6.76	0.5%
Total	**869.28**		**139.71**	**178.76**	**313.77**	**387.48**		**1256.8**	

B0(=log K	2.389	K =	244.9063
B1(=n)	0.212	N=	0.212
		N-1 =	-0.788

Extraction Rates (ug/day)

Day	
1	51.92
7	11.20
14	6.49

Dynamic Extraction Study - Test Results and Data Analysis

Test Material: Innomag — Serial Numbers: 16423

Model No: U-MAG.U1 (code: U11561102-UDO)

Leachate Type:	35% HCl
Initial Fill Volume:	2.722 liters
Sample+Rinse Volume 0:	0.175 liters
Sample+Rinse Volume 1:	0.171 liters
Sample+Rinse Volume 2:	0.169 liters
Sample+Rinse Volume 3:	0.171 liters
Sample+Rinse Volume 4:	0.181 liters

Date		01/18/11	01/18/11	01/18/11	01/18/11	01/20/11	01/28/11
Time		8:00	8:41	10:00	16:18	13:15	9:37
Time (hours)	Detection Limit	Control	0.00	1.32	7.62	52.57	240.93
			Concentration (ppb)				

	Day>>>	Surface	% of Surface	Cumulative Metal Extraction (ug) 0.055	0.317	2.190	10.039		Total	% of Total
				Extracted						
Ag	Ag	0.00	0.0%	0.00	0.00	0.02	0.0	0.0%	-0.05	0.0%
Al	Al	39.43	4.5%	10.76	19.09	26.02	40.0	7.8%	79.41	5.7%
As	As	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Au	Au	0.00	0.0%	0.00	0.00	0.00	-0.1	0.0%	-0.09	0.0%
B	B	2.95	0.3%	6.34	13.54	20.43	20.7	4.0%	23.60	1.7%
Ba	Ba	6.79	0.8%	2.59	5.04	6.93	9.0	1.7%	15.78	1.1%
Be	Be	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Bi	Bi	59.56	6.8%	98.23	118.64	141.03	163.3	31.6%	222.84	16.0%
Ca	Ca	45.80	5.2%	6.67	12.31	17.20	23.2	4.5%	68.99	5.0%
Cd	Cd	0.79	0.1%	1.64	1.51	3.46	1.3	0.2%	2.05	0.1%
Co	Co	0.64	0.1%	0.13	0.14	0.15	0.2	0.0%	0.83	0.1%
Cr	Cr	21.90	2.5%	1.64	4.99	4.51	3.0	0.6%	24.90	1.8%
Cs	Cs	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Cu	Cu	40.89	4.7%	2.06	14.48	10.37	13.6	2.6%	54.52	3.9%
Fe	Fe	534.43	61.0%	23.75	45.82	56.00	65.3	12.6%	599.69	43.1%
Ga	Ga	0.48	0.1%	0.19	0.33	0.50	0.6	0.1%	1.09	0.1%
In	In	0.94	0.1%	0.19	0.24	0.41	0.2	0.0%	1.12	0.1%
K	K	2.80	0.3%	0.78	1.23	2.41	4.5	0.9%	7.32	0.5%
Li	Li	0.06	0.0%	0.10	0.18	0.22	0.3	0.1%	0.32	0.0%
Mg	Mg	16.40	1.9%	5.74	11.04	20.00	34.5	6.7%	50.87	3.7%
Mn	Mn	3.41	0.4%	0.44	0.16	0.27	0.2	0.0%	3.66	0.3%
Mo	Mo	0.59	0.1%	0.13	0.31	0.38	0.5	0.1%	1.09	0.1%
Na	Na	4.96	0.6%	1.89	2.69	4.17	6.6	1.3%	11.56	0.8%
Nb	Nb	0.05	0.0%	0.03	0.09	0.13	0.1	0.0%	0.20	0.0%
Nd	Nd	0.52	0.1%	0.04	0.04	0.06	0.1	0.0%	0.60	0.0%
Ni	Ni	23.84	2.7%	0.63	3.90	2.45	5.8	1.1%	29.68	2.1%
Pb	Pb	3.83	0.4%	0.17	0.32	0.26	0.4	0.1%	4.19	0.3%
Rb	Rb	0.00	0.0%	0.00	0.00	0.01	0.0	0.0%	0.02	0.0%
Re	Re	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
Sn	Sn	23.92	2.7%	58.62	58.43	62.41	62.4	12.1%	86.33	6.2%
Sr	Sr	0.43	0.0%	0.06	0.10	0.15	0.2	0.0%	0.63	0.0%
Ti	Ti	9.65	1.1%	10.74	26.62	35.94	37.5	7.3%	47.14	3.4%
Tl	Tl	0.00	0.0%	0.00	0.00	0.00	0.0	0.0%	0.00	0.0%
U	U	0.01	0.0%	0.00	0.00	0.00	0.0	0.0%	0.01	0.0%
V	V	4.59	0.5%	4.92	11.20	14.05	14.0	2.7%	18.63	1.3%
W	W	0.57	0.1%	0.09	0.17	0.34	0.5	0.1%	1.11	0.1%
Zn	Zn	23.87	2.7%	3.08	3.10	3.65	4.2	0.8%	28.08	2.0%
Zr	Zr	1.35	0.2%	0.75	2.46	3.24	3.9	0.8%	5.24	0.4%
	Total	**875.4**		**242.40**	**358.18**	**437.15**	**515.96**		**1391.4**	

B0(=log K	2.584	K =	383.7072	
B1(=n)	0.140	N=	0.14	
		N-1 =	-0.86	

Extraction Rates (ug/day)

Day	
1	53.72
7	10.08
14	5.55