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UNCC's "Sorption Evaluation for Ash Basin Closure – H.B. Robinson Steam Station" Report

Sorption Evaluation for Ash Basin Closure
H. B. Robinson Steam Station

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1. Introduction

Duke Energy Progress (Duke Energy) owns and operates the H.B. Robinson Steam Electric Plant (Robinson Plant) located near Hartsville in Darlington County, South Carolina (Figure 1). The Robinson Plant coal ash management facilities include a former 177-megawatt coal-fired unit (Unit 1), one ash basin located north of the Robinson Plant and west of Lake Robinson, and an older ash storage area (1960 Fill Area) located west of Unit 1 (Figure 2). Coal ash residue generated during the coal combustion process at Unit 1 was stored in the 1960 Fill Area from 1960 until the mid-1970s when the approximate 72-acre ash basin was constructed. The ash basin continued to receive coal ash residue until October 2012 when Unit 1 was retired.

Duke Energy retained HDR to develop a Conceptual Closure Plan (Plan) for the Robinson Plant ash basin. To do so, HDR implemented a geotechnical and environmental exploration program between July and November 2014 that consisted of soil boring completion; monitoring well installation; index property testing of soil and ash; constituent testing of soil, ash, groundwater, and free water; and in-situ hydraulic conductivity testing. The data derived from the field program is being evaluated to achieve the following project objectives:

- Determine the amount of coal ash residue in the ash basin and 1960 Fill Area
- Characterize subsurface materials within the ash management areas, down-gradient of the ash basin, and in background areas of the site
- Develop a Site Conceptual Model (SCM) to serve as the basis for understanding the hydrogeologic characteristics of the site and ash basin (both existing and under the preferred closure option).
- Use the SCM to develop a conceptual plan for closure of the ash basin that is protective of human health and the environment and acceptable to SCDHEC Bureau of Water per their guidance *Proper Closeout of Wastewater Treatment Facilities*, *Regulation 61-82*, dated April 11, 1980

The subsurface investigation included completion of 22 environmental soil borings; 11 geotechnical soil borings; installation of 30 groundwater monitoring wells; and subsequent soil, ash, groundwater, and free water sample collection and testing. Soil boring and monitoring well locations are shown on Figure 3.

Closure of the 1960 Fill Area will be regulated under a Consent Agreement between Duke Energy and the SCDHEC Bureau of Solid Waste. However, the final disposition of ash within the 1960 Fill Area will likely be incorporated into closure of the ash basin.

A Conceptual Closure Planning document was submitted to SCDHEC as an update of Duke Energy's progress to date on the Robinson Ash Basin Closure Investigation and describe future work activities that will support development of a preferred ash basin closure plan. A summary of data and information collected as part of the Robinson Ash Basin Closure Investigation, along with a summary of results, is provided in this update report. A more detailed description of data

collected, methodologies used, and testing results is provided in the companion Robinson Ash Basin Closure Investigation Data Report (HDR 2014).

In letter dated January 16, 2015, Duke Energy provided SCDHEC with the following milestone schedule for providing an update on their ash basin conceptual closure planning:

2/16/15 – 2/27/15	Fieldwork for collecting second set of groundwater well samples
3/13/15	Completion of soil sorption (K_d) testing
4/17/15	Completion of groundwater modeling using the Fall and Winter sample data sets
Week of 4/27/15	Meeting with SC DHEC to discuss modeling results and next steps

2. Purpose

Groundwater fate and transport modeling of dissolved constituents of concern (COCs) will be performed to support development of the conceptual ash basin closure report. Data requirements for the modeling effort include site-specific sorption coefficients, or K_d terms, for native soils surrounding the ash basin unit. The purpose of this report is to present the results of sorption testing on selected soils from the Robinson site and quantify the K_d terms. The testing was performed at the Civil & Environmental Engineering laboratories in the EPIC building at UNC Charlotte. Soil samples were collected during the geotechnical and environmental exploration program at the Robinson Plant between July and November 2014, seventeen of which were delivered to UNC-Charlotte on July 24 and October 1 of 2014.

3. Background

In groundwater, sorption is quantified by the equilibrium relationship between chemicals in the dissolved and adsorbed phases. Experiments to quantify sorption can be conducted using batch or column procedures. A batch sorption procedure consists of combining soil samples and solutions across a range of soil-to-solution ratios, followed by shaking until chemical equilibrium is achieved. Initial and final concentrations of chemicals in the solution determine the adsorbed amount of chemical, and provide data for developing plots of adsorbed versus dissolved chemical and the resultant partition coefficient K_d, with units of volume per unit mass. If the plot, or isotherm, is linear, the single-valued coefficient K_d represent the slope of the isotherm. Depending on the chemical and its concentration, and the soil characteristics, non-linear isotherms may also result. The column sorption procedure consists of passing a solution of known chemical concentration through a cylindrical column packed with the soil sample. A plot of the chemical constituent measured in the column effluent is plotted versus time. This so-called breakthrough curve is matched to the Ogata and Banks (1961) solution of the advection-dispersion-adsorption equation from which the linear partition coefficient K_d is estimated by curve fitting. When considering the merits of the two procedures for characterizing sorption, the batch procedure provides the most effective contact between the solution and soil, while the column procedure is more representative of in-situ groundwater flow conditions where solution-soil contact is non-uniform and less than fully effective. Thus, column-derived sorption coefficients are generally less than their batch-derived counterparts. Both batch and column

procedures were employed for the sorption experiments on soils from the Robinson Plant. The batch procedure may designed to capture a wide range of potential K_ds. Also a comparison of K_ds from both methods for each soil provides confirmation of the overall result.

4. Selection and Preparation of Soil Samples

A total of 13 soil samples were selected for determination of sorption coefficients (Table 1). The basis for selection was to provide adequate coverage of the saturated zone beneath and down gradient of the ash basin. Unpreserved soils arrived at the EPIC lab in five-gallon plastic buckets with lids. Samples were disaggregated, homogenized, and dried at room temperature in aluminum pans (21” x 13” x 4”), for a minimum of 72 hours, with turning every 12 hours. The dry samples were then sieved to a particle diameter of less than 2 mm.

Soil samples for batch sorption tests were weighed and placed in 250 mL wide-mouth HDPE bottles with polypropylene screw tops. For each test on a single sample, soil masses of 10, 25, 50, 75, and 100 grams were placed in separate bottles.

The columns are 8” long, polypropylene tubes (⅝” O.D x ¾" I.D.) with serrated, tapered-end caps that accept ¼” to ⅜" I.D. tubing. Each end of the column assembly has discs of polypropylene mesh (31 by 31) and a thin, HDPE fiber mat to support and retain the soil sample in the column between the column and the pressure-fit end cap. With one end cap attached to the column, acid-washed Ottawa sand was added through the open end of the column to a depth of about 2 cm. The coarse sand layer ensured the effective dispersal of flow across the column cross section at its entrance. After weighing the column, lower end cap, and sand, the column was filled with soil sample in 5 cm lifts. Between each lift, the sample was lightly compacted to achieve a uniform density based on visual inspection. After weighing the column assembly (lower end cap, sand, and sample), a 2 cm thick sand layer was added at the top of the compacted sample and the upper end cap was attached. The soil column weights and dimensions are summarized in Table 3.

5. Test Solutions and Equipment Setup

Based on groundwater monitoring well sample results for major anions and cations from the Robinson Ash Basin Closure Investigation Data Report (HDR 2014), a generic background solution was developed for the sorption experiments (Table 3). Concentrations of major cations and anions in the solution were obtained in Table 3 by adding solid reagent grade chemicals to reagent grade water (ASTM Standard D1193).

Concentrations of COCs for sorption determination were obtained by diluting concentrated reference standards with the background solution (Table 4). After adding the acidified reference standards, the intermediate pH values of the COC-amended solutions were less than 2. Both solutions were then back-titrated to the target pH using 1N potassium hydroxide. Iron and manganese were considered separately in the batch experiments at a reduced pH in order to increase their solubility. This list of COCs was provided by verbal communication with HDR on January 15, 2015.

The COC-amended solutions were prepared in 10 liter and 20 liter LDPE carboys for the batch and column experiments, respectively. For each batch experiment, 200 ml of solution was added to each 250 ml bottle to obtain soil mass to solution ratios of 50, 125, 250, 375, and 500 mg/l. The soil-solution mixtures were equilibrated in a rotary mixer operating at 60 rpm for 24 hours (Figure 4). Following equilibration, water samples were drawn, filtered, and preserved for the analyses listed in Table 5. Sample blanks were included in selected experiments to confirm stability of the solution.

For the column experiments, Masterflex peristaltic pump drives with 12-channel, 8-roller cartridge pump heads and cartridges were connected between the carboys and the columns using Tygon tubing, valves, and fittings. The columns were operated in the upflow mode. The flow rate was set to pass approximately twelve pore volumes, or approximately 200 ml, per day through each column. Before pumping began with the COC-amended solutions, the columns were fully saturated by slowly pumping reagent water in the upflow mode. The COC-amended solutions were stirred continuously using magnetic stirrers. The arrangement of the carboys, pump, and columns is shown in Figure 4. Real-time, grab sample volumes of approximately 15 ml were drawn for each sampling event. The sample time and total volume pumped since the previous sampling event were recorded for calculating flow rates and pore volume passed. Concurrent samples of the feed solutions were also taken for each sampling event. Each sample was proportioned, filtered, and preserved for the analyses listed in Table 5.

6. Model Equations for K_d Determination

After equilibration of a batch soil-solution mixture, the COC concentration in solution will be reduced due to sorption. This may be expressed as

$$x/m = [(Co-C)/m]*V$$

Where x/m is the soil concentration (µg/g), Co is the initial solution concentration (µg/L), C is the final solution concentration, m is the soil sample mass, and V is the volume of solution. For sorption characterized by a linear isotherm, a plot of measured solution concentration versus calculated soil concentration for each soil sample (five data points: one for each soil to solution ratio) will yield the linear K_d term as the slope of x/m versus C.

For the steady-state flow regime considered in the column tests, van Genuchten and Alves (1982) presented the following form of the Ogata-Banks (O-B) equation for one-dimensional, advection-dispersion equation with sorption as a close approximation to that for a finite length, lab-scale column:

$$C(x,t) = \frac{C_0}{2}\left[erfc\left(\frac{Rx - vt}{2\sqrt{DRt}}\right) + exp(vx/D)erfc\left(\frac{Rx + vt}{2\sqrt{DRt}}\right)\right]$$

where C(x,t) is the solute concentration (M/L^3), x is the column length (L), t is the elapsed time (T), C_0 is the feed concentration (M/L^3), R is the dimensionless retardation coefficient, v is the

seepage velocity (L/T), and D is the soil dispersion coefficient (L^2/T). For sorption characterized by a linear isotherm, the K_d term (L^3/M) is incorporated in R:

$$R = 1 + \frac{\rho_b K_d}{n}$$

where ρ_b is the dry bulk density of the soil (M/L^3) and n is the porosity. For the given test conditions where dispersion was dominant over diffusion, the soil dispersion coefficient D is equal to the product of the longitudinal dispersivity a_L (L) and the seepage velocity. Supporting data used to estimate K_d based on O-B equation are provided in Table 6. For plotting the analytical results together with the O-B equation, cumulative pore volumes corresponding to the elapsed time of each sampling event were calculated using measured water volumes pumped and the column pore volume. For each COC and soil column, K_d was estimated by fitting the plotted O-B equation to the measured solution concentrations.

7. Results

The sorption test results are grouped by soil sample and test method. Column test results for each of the thirteen soils tested are shown in Figures 6 (a-k) through 18 (a-k). Batch test results are shown in Figures 19 (a-k) through 32 (a-k). Batch test results using an iron and manganese amended test solution for two soils are shown in Figures 32 (a-e) and 33 (a-e). Duplicate batch results for one soil sample are shown in Figures 34 (a-k). Estimated K_ds by soil sample and test method are presented in Table 7.

Column test results for the six COCs consisting of boron (B), manganese (Mn), arsenic (As), molybdenum (Mo), iron (Fe), and barium (Ba) are shown the series of figures labeled (a) through (f), respectively, for each soil sample. Sensitivity of the Ogata-Banks (O-B) solution to K_d is shown by bracketing the observed best fit with high and low values. The results by are summarized by COC as follows.

- For each soil tested, B breakthrough occurred very soon after initiating the test. That is, B was measured in the column effluent at a concentration exceeding one half of the test solution soon after passage of the first pore volume of solution through each column. Fitting these results to the Ogata-Banks (O-B) solution indicate that K_d in ml/gr is in the low single digits.
- K_d for As ranged from about 16 to greater than 100 ml/gr.
- K_d for Mo ranged from less than 1 to greater than 60. Two soils exhibited high K_d values for Mo (DD-2-33 and DD-2-53), while the remainder were significantly lower.
- When fitted to the later part of the breakthrough curves, K_d for Ba ranged from mid-single digits to greater than 40 ml/kg. Potential Ba leaching is indicated by its occurrence in the effluent soon after passage of the first pore volumes of test solution.

- Mn was not included in the test solution, so its occurrence in the effluent is indicative of leaching. Mn was observed to decrease or vary with the passage of additional pore volumes over the course of the experiment.
- Fe was also not included in the test solution, so its occurrence in the effluent is indicative of leaching. In general, Fe was observed to decrease with the passage of additional pore volumes over the course of the experiment.
- The variation in measured water quality parameters shown in figure series (g) through (k), including anions added to the test solution (sulfate and nitrate), pH, conductivity, and oxidation-reduction potential (ORP), suggest that changes in overall water chemistry of the test solution due to exposure to soils is limited.
- Anomalies noted for the column tests include the response of As in columns AP-2 and MW-113D/CB-2 where the concentrations indicated concentration peaks followed by significant declines. This may be due to a transient, short circuit of test solution through the soil column.

Batch test results for the six COCs are shown the series of figures labeled (a) through (f), respectively, for each soil sample. The results by are summarized by COC as follows:

- The response of B in the batch tests was not linear due to the very low sorption capacity of the soils for this COC. This result is consistent with the column test results.
- K_d for As ranged from about 110 to greater than 700 ml/gr. With one exception (MW-113D/CB-2) the correlation coefficients were high, indicating the linear sorption model is valid.
- K_d for Mo ranged from single digits to about 200. The calculated K_d for DD-2-53 may not be valid because of the narrow, low range of concentrations used for its estimation.
- K_d for Ba ranged from single digits to about 35. The observed non-linear response of Ba may be due in part to its leaching. This was observed at the double-digit ppb level for each soil sample in the Fe-Mn batch test.
- Mn was not included in the test solution, so its occurrence in the batch test solution is indicative of leaching. In the (b) series of Figures 19 though 32, the mass of soil per unit volume of test solution is related to the observed Mn concentration in the test solution by a linear correlation.
- Fe was not included in the test solution, so its occurrence in the batch test solution is indicative of leaching. In the (e) series of Figures 19 though 32, the mass of soil per unit volume of test solution is related to the observed Fe concentration in the test solution by a linear correlation. With two exceptions, the fit of the data does not indicate a linear correlation.
- As with the column test, the variation in measured water quality parameters shown in the figure series (g) through (k), including anions added to the test solution (sulfate and nitrate), pH, conductivity, and oxidation-reduction potential (ORP), suggest that changes in overall water chemistry of the test solution due to exposure to soils is limited.

- Duplicate batch test results for soil sample AP-2 are shown in Figures 34 (a-k) for direct comparison with Figures 20 (a-k).

Batch test results using an Fe and Mn amended test solution for two soils are shown in Figures 32 (a-e) and 33 (a-e). Concentrations of both Fe and Mn increased with mass of soil per unit volume of test solution, indicating that a linear leaching model is applicable, as opposed to a linear sorption model.

REFERENCES

HDR, Robinson Ash Basin Closure Investigation, Conceptual Closure Planning Update, H.B Robinson Steam Electric Plant, Darlington County, SC, December 2014.

Ogata A. and Banks, R.B., “A solution to the differential equation of longitudinal dispersion in porous media” Professional Paper No. 411-A, U.S. Geological Survey, Washington D.C., 1961.

van Genuchten, M. Th., and Alves, W. J., Analytical Solutions of the One-Dimensional Convective-Dispersive Solute Transport Equation, U.S. Department of Agriculture, Technical Bulletin No. 1661, 151 p., 1982.

Table 1. Soils selected for Kd determination		
HDR designation	**sample date**	**depth (feet)**
AP-1/AP-3	7/16/2014	43-45
AP-2	8/6/2014	65
AP-3	7/16/2014	43-45
AP-4	7/16/2014	48-50
AP-6	7/15/2014	48-50
AP-7	7/15/2014	48-50
AP-10	8/6/2014	45-50
MN-110D/AP-10	N/A	55-56
DD-2	8/4/2014	33
DD-2	8/4/2014	53
MW-101D/BG-2	N/A	35-37
MW-113D/CB-2	N/A	43-45
CB-3	7/18/2014	38-40

Table 2. Soil column data					
Sample	soil weight g g	volume ml ml	bulk density g/ml	porosity	pore volume ml
AP-1	46.57	32.66	1.43	0.46	15.09
AP-2	41.92	32.66	1.28	0.52	16.84
AP-3	47.56	32.86	1.45	0.45	14.91
AP-4	43.63	32.86	1.33	0.50	16.39
AP-6	45.25	32.86	1.38	0.48	15.78
AP-7	42.33	31.87	1.33	0.50	15.89
AP-10	39.51	31.67	1.25	0.53	16.76
MN-110D/AP-10	41.96	32.07	1.31	0.51	16.23
DD-2-33	39.97	32.66	1.22	0.54	17.58
DD-2-53	40.38	32.66	1.24	0.53	17.42
MW-101D/BG-2	48.03	32.36	1.48	0.44	14.24
MW-113D/CB-2	45.98	32.66	1.41	0.47	15.31
CB-3	44.35	33.05	1.34	0.49	16.32

Table 3. Background water solution chemistry				
compound	target cation	mg/l	target anion	mg/l
$CaSO_4$	Ca^{+2}	29	SO_4^{-2}	71
$NaNO_3$	Na+	4	NO_3-	11

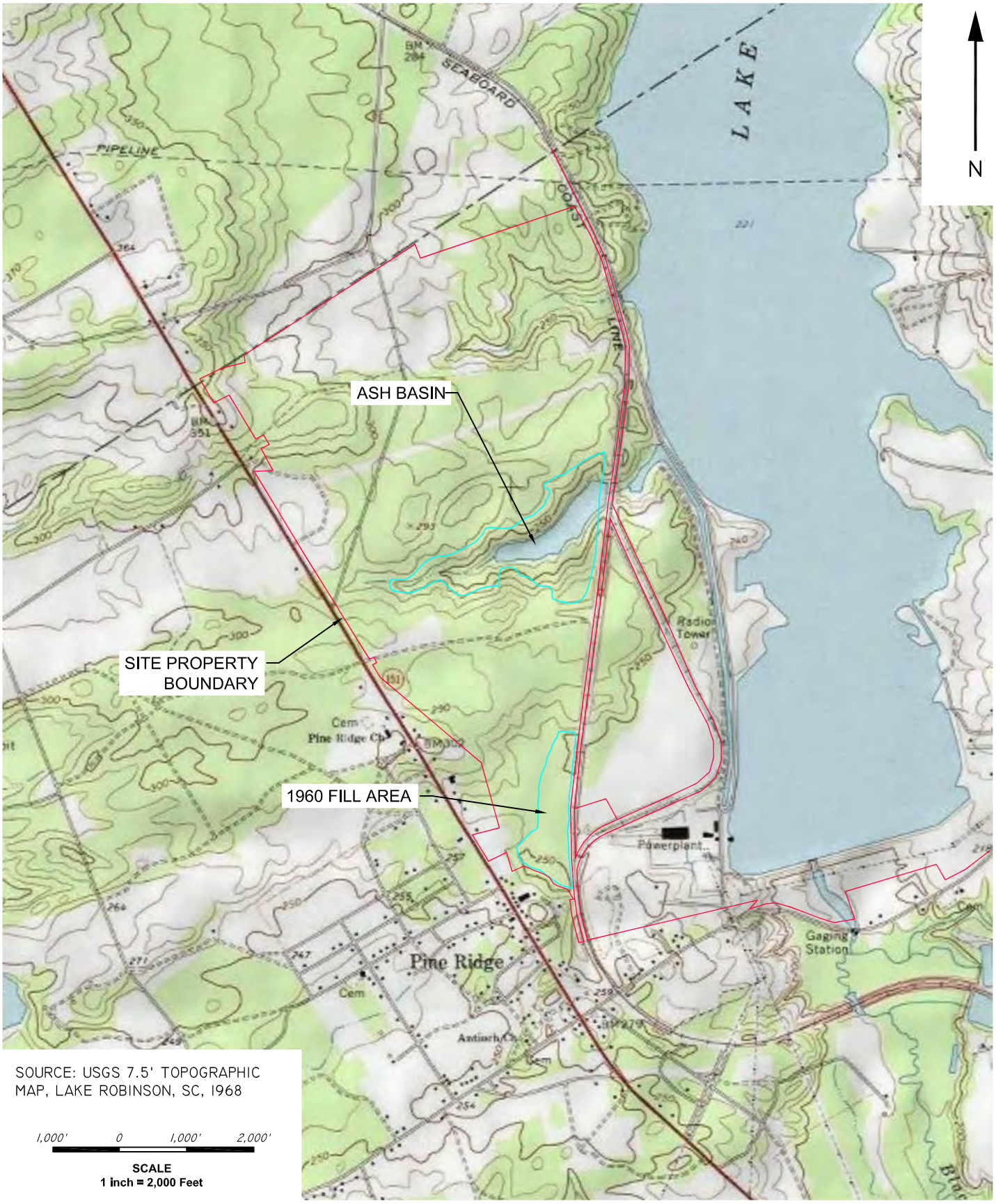
Table 4. COCs and target solution parameters			
COC	target concentration mg/l	target pH	test method(s)
As	0.5	7	column and batch
B			
Ba			
Mo			
Fe		5.8	batch only
Mn			

Table 5. Analytical methods, equipment, and preparation for water samples			
analyte	method	equipment	sample preparation
As, B, Ba, Fe, Mn, Mo	EPA 200.8	Thermo X Series ICP-M.S.	0.45 um filtration, acidify to pH < 2,
chloride, sulfate, nitrate	EPA 300.0	Dionex DX500	
pH	user's manual	Mettler Toledo S470-Bio	none
conductivity			
redox potential			

Table 6. Supporting data for estimating Kd by Ogata-Banks equation		
parameter	units	value
average flow rate	ml/day	200
column cross-sectional area	cm2	1.92
porosity		0.5
seepage velocity	cm/day	202.1
estimated dispersivity	cm	1
Dispersion coefficient	cm2/day	3.6

Table 7. Estimated Kd terms for selected soil samples
(all results in ml/gram)

Soil sample	Boron		Arsenic		Molybdenum		Barium	
	batch	column	batch	column	batch	column	batch	column
AP-1	0.29	4	260.7	28	103.9	8	8.3	8
AP-2	1.64	4	115.1	20	12.3	4	29.4	24
AP-3	0.46	2	371.6	26	8.1	8	27.2	10
AP-4	0.12	1.5	293.5	28	199.6	8	6.6	14
AP-6	1.06	4	206.4	20	10.3	4	25.6	14
AP-7	1.27	1.5	798.5	20	24.4	4	44.7	24
AP-10	1.70	1.5	176.6	70	3.6	2	26.4	19
MW-110D/AP-10	1.46	1.5	145.7	70	3.0	2	32.9	16
DD-2-33	0.79	2	187.9	100	4.0	60	35.1	48
DD-2-53	0.50	1.5	711.4	100	6390.0	70	22.4	48
MW-101D/BG-2	0.79	1.5	432.9	66	8.4	3	24.9	12
MW-113D/CB-2	0.32	1.5	202.8	46	74.5	8	6.5	14
CB-3	0.11	1.5	276.0	34	58.3	10	10.0	14



SITE LOCATION MAP
H.B. ROBINSON STEAM ELECTRIC PLANT
DUKE ENERGY PROGRESS
DARLINGTON COUNTY, SOUTH CAROLINA

DATE
DECEMBER 17, 2014

FIGURE
1

LEGEND:

- PROPERTY BOUNDARY
- ASH BASIN BOUNDARY
- 1960 FILL AREA BOUNDARY
- WATER BODY
- TOPOGRAPHIC CONTOURS

SCALE (FEET)

300' 0 300' 600'

1" = 600'

North Carolina Engineering Firm Number: F-0116
440 South Church Street Charlotte, NC 28202

SITE LAYOUT MAP
ASH BASIN CLOSURE
DUKE ENERGY PROGRESS
ROBINSON PLANT - ASH BASIN CLOSURE PROJECT
DARLINGTON COUNTY, SOUTH CAROLINA

DATE
12/10/2014

FIGURE
2

SCALE (FEET)

200' 0 200' 400'

1" = 400'

HDR

North Carolina Engineering Firm Number: F-0116
440 South Church Street Charlotte, NC 28202

MONITORING WELL AND BORING LOCATION MAP
ASH BASIN CLOSURE (ASH BASIN)
DUKE ENERGY PROGRESS
ROBINSON PLANT - ASH BASIN CLOSURE PROJECT
DARLINGTON COUNTY, SOUTH CAROLINA

DATE
12/17/2014

FIGURE
3

Figure 4. Batch soil samples in rotary mixer

Figure 5. Column soil sample arrangement

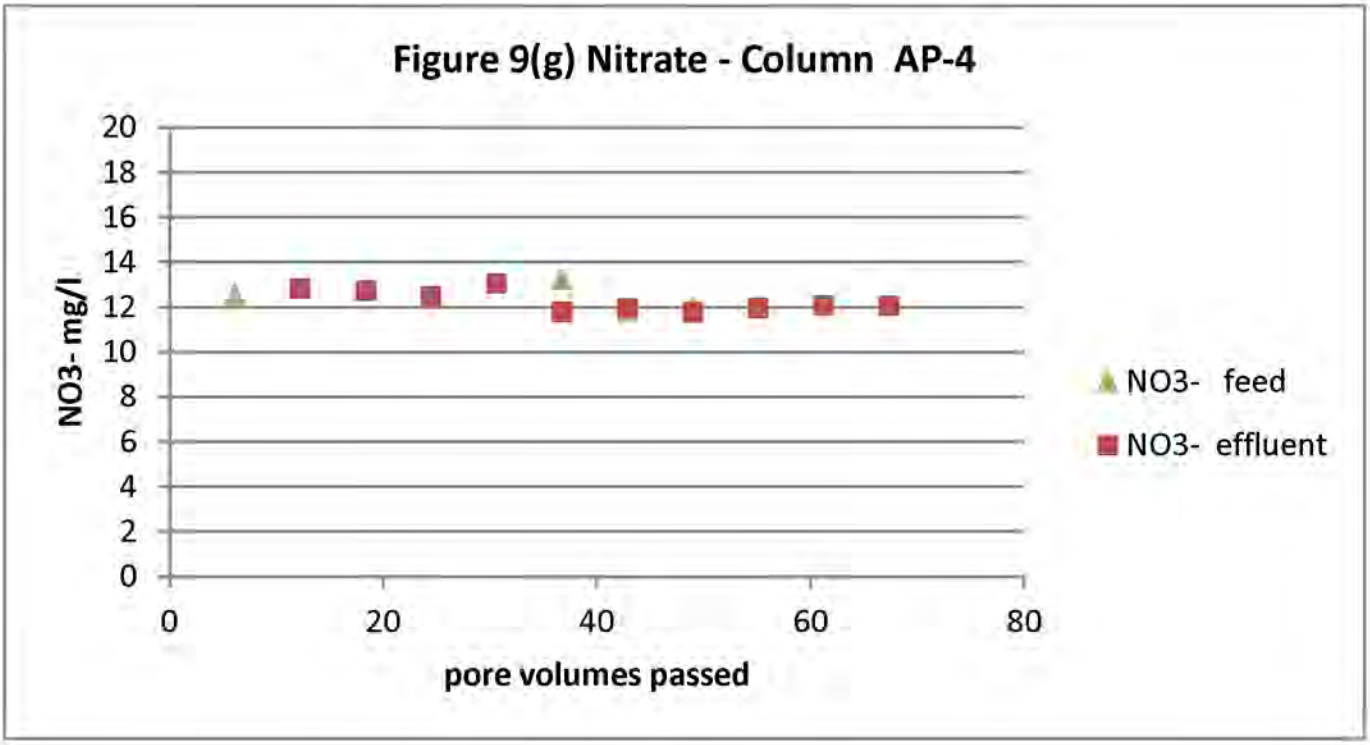


Figure 9(g) Nitrate - Column AP-4
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

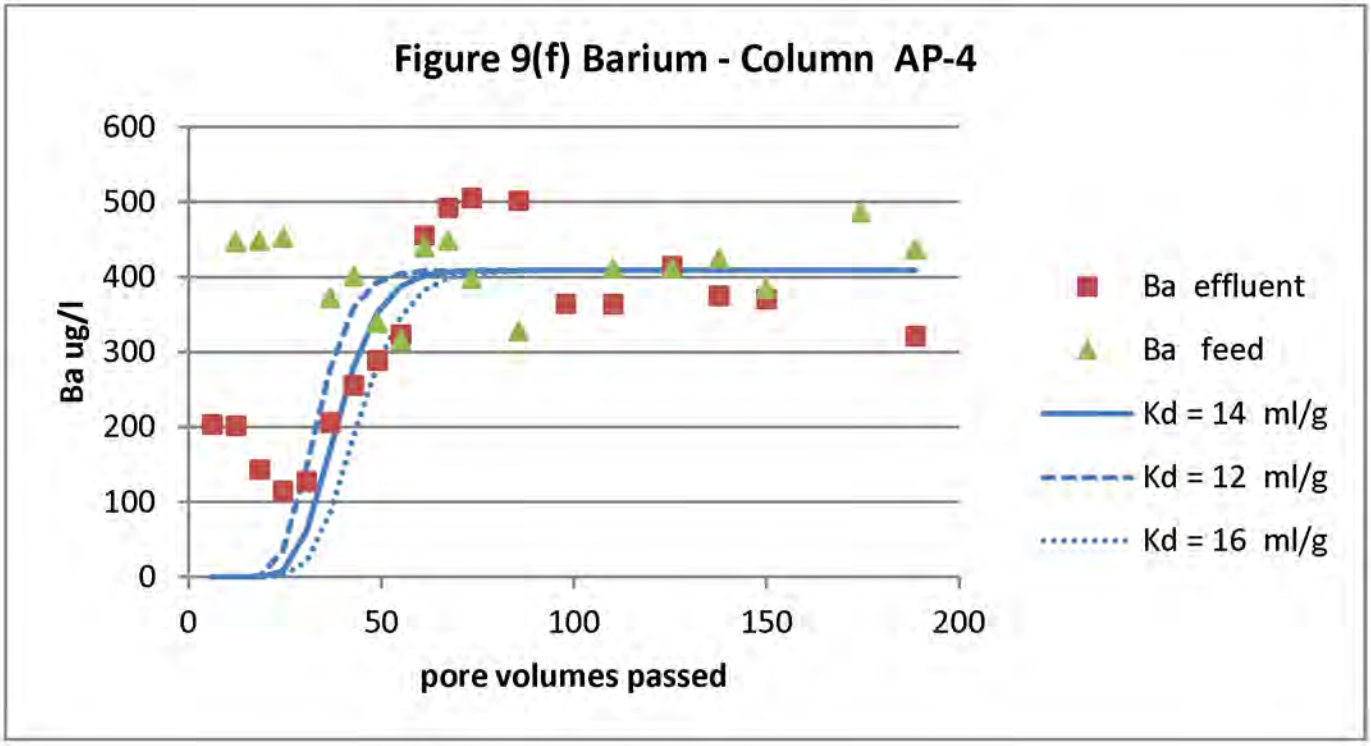


Figure 9(f) Barium - Column AP-4
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 14 ml/g
Kd = 12 ml/g
Kd = 16 ml/g

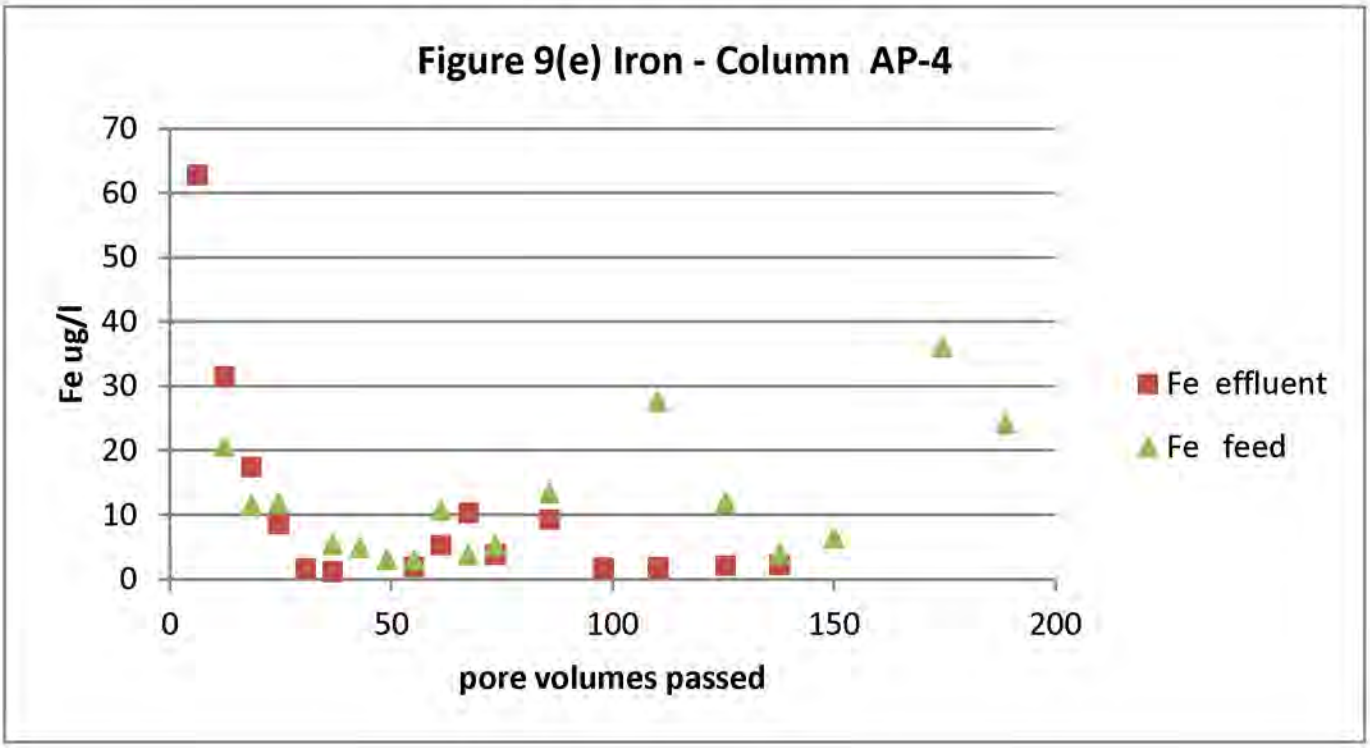


Figure 9(e) Iron - Column AP-4
70
60
50
40
30
20
10
0
Fe ug/l
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

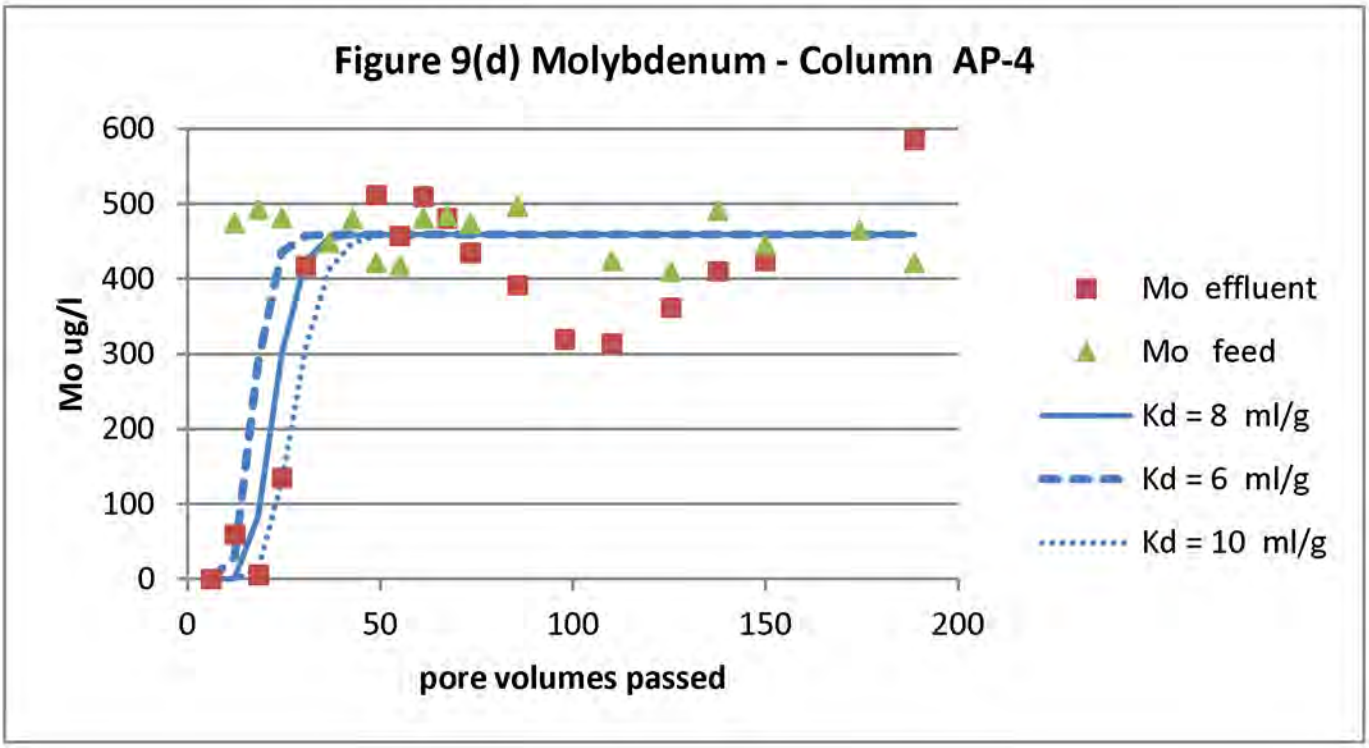


Figure 9(d) Molybdenum - Column AP-4
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 8 ml/g
Kd = 6 ml/g
Kd = 10 ml/g

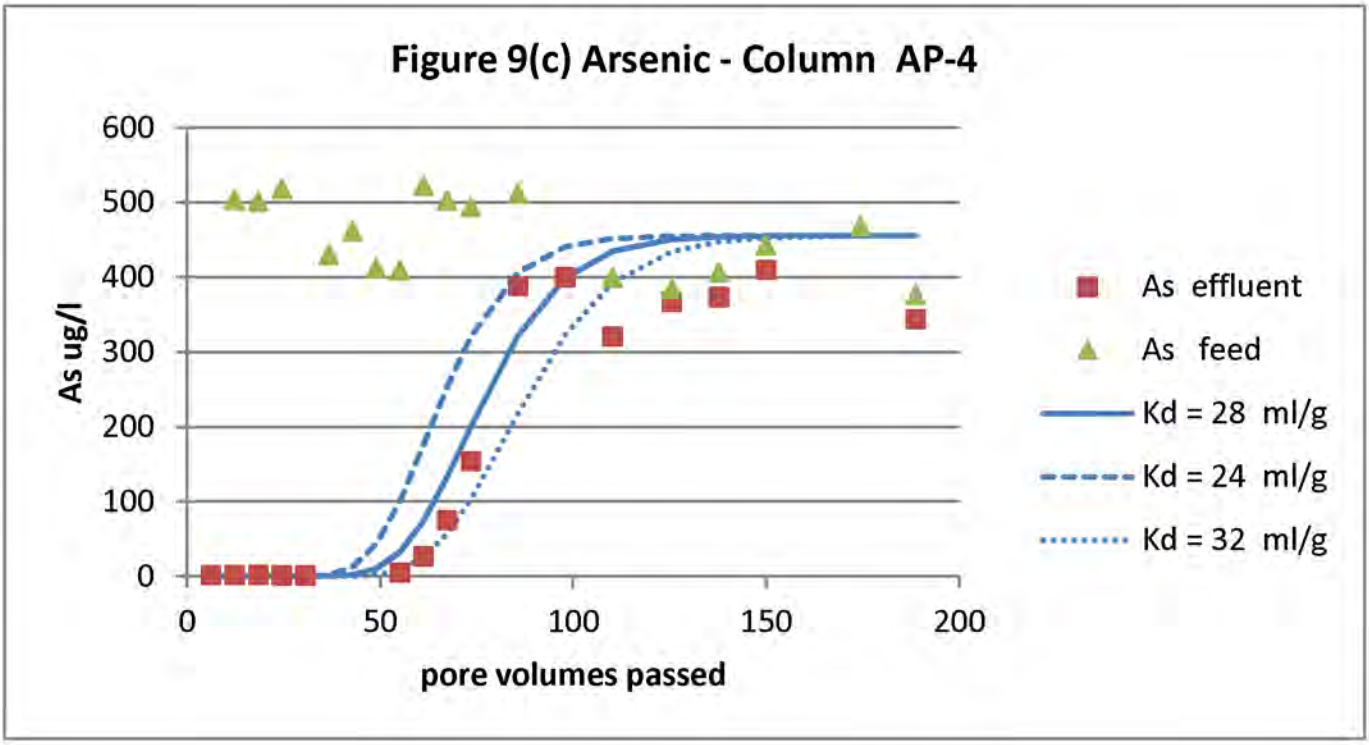


Figure 9(c) Arsenic - Column AP-4
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 28 ml/g
Kd = 24 ml/g
Kd = 32 ml/g

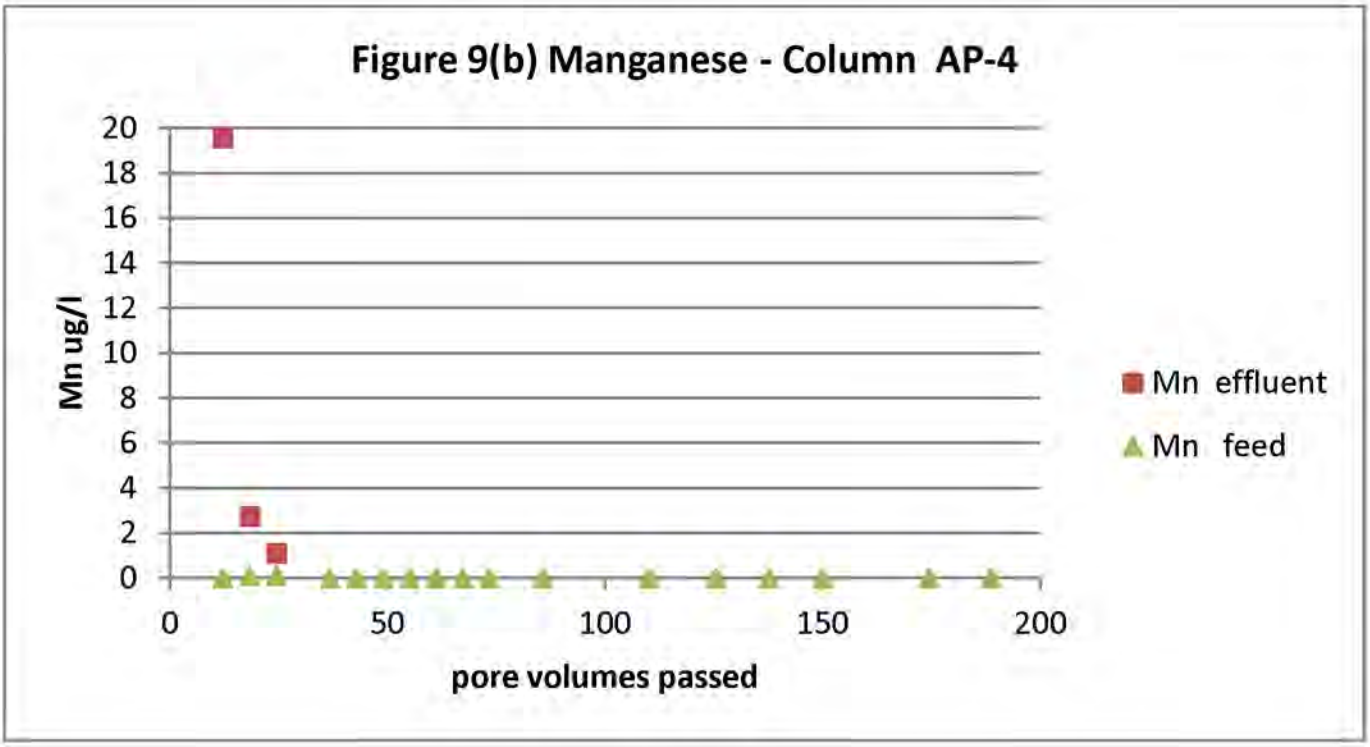


Figure 9(b) Manganese - Column AP-4
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

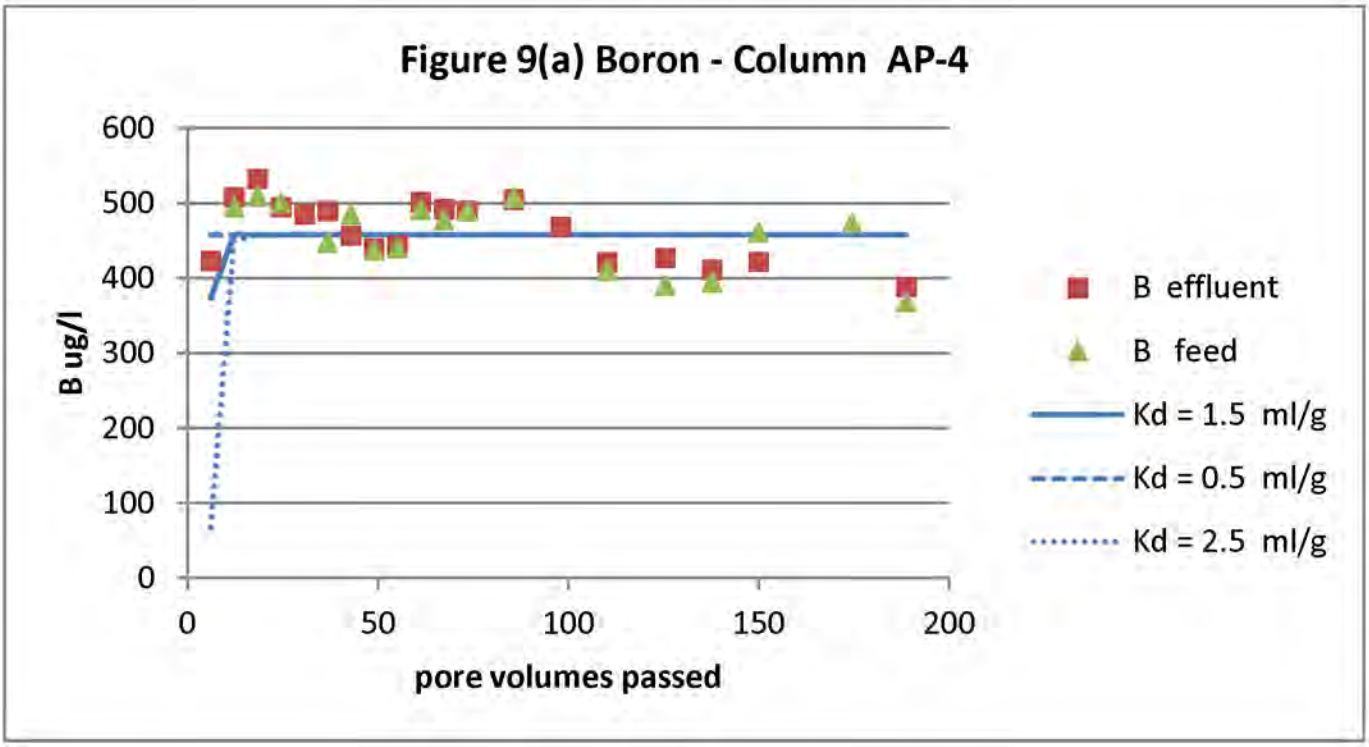


Figure 9(a) Boron - Column AP-4
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 1.5 ml/g
Kd = 0.5 ml/g
Kd = 2.5 ml/g

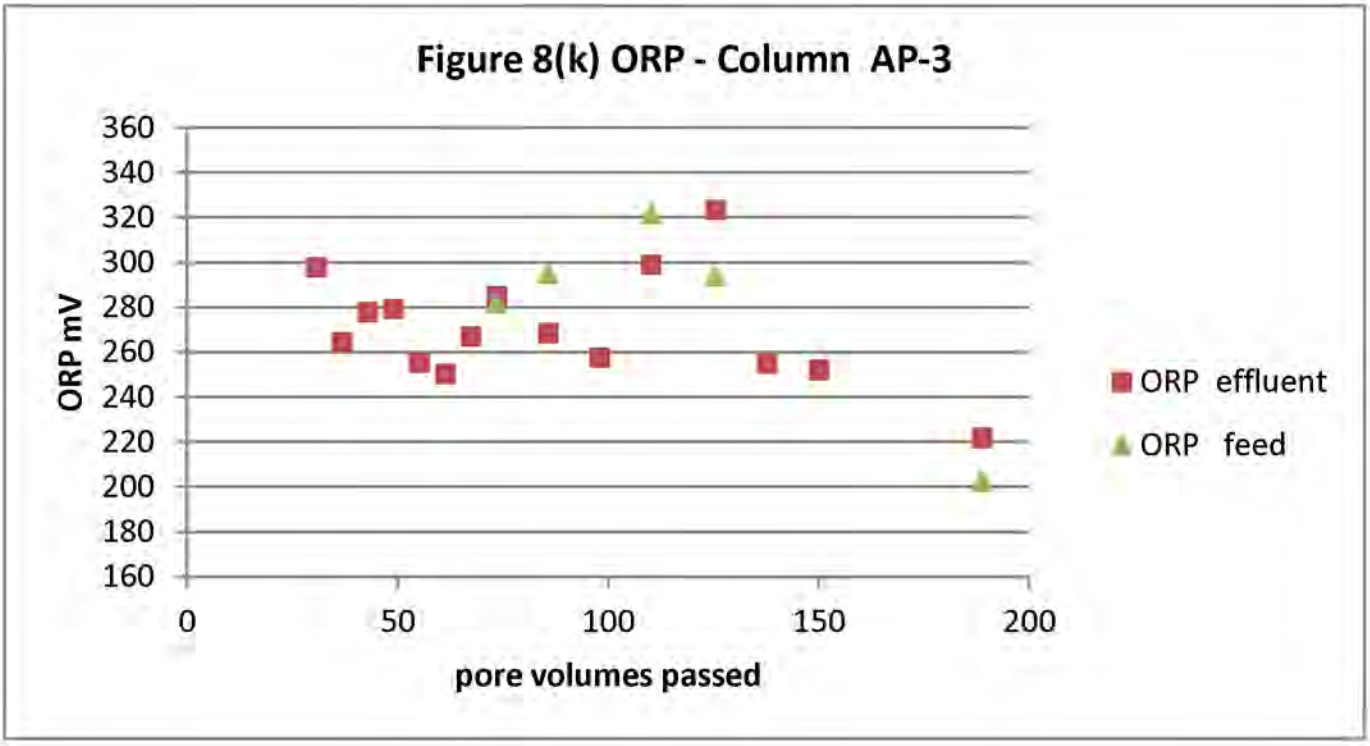


Figure 8(k) ORP - Column AP-3
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

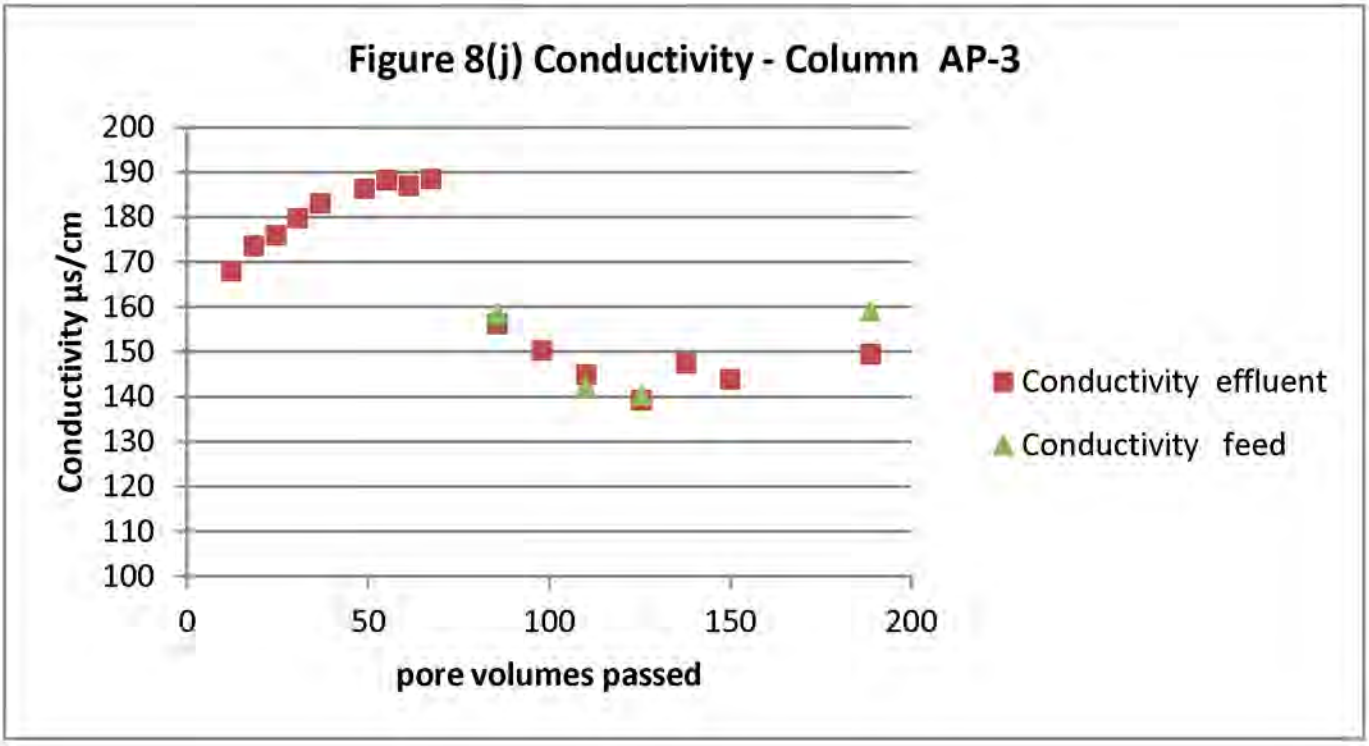


Figure 8(j) Conductivity - Column AP-3
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

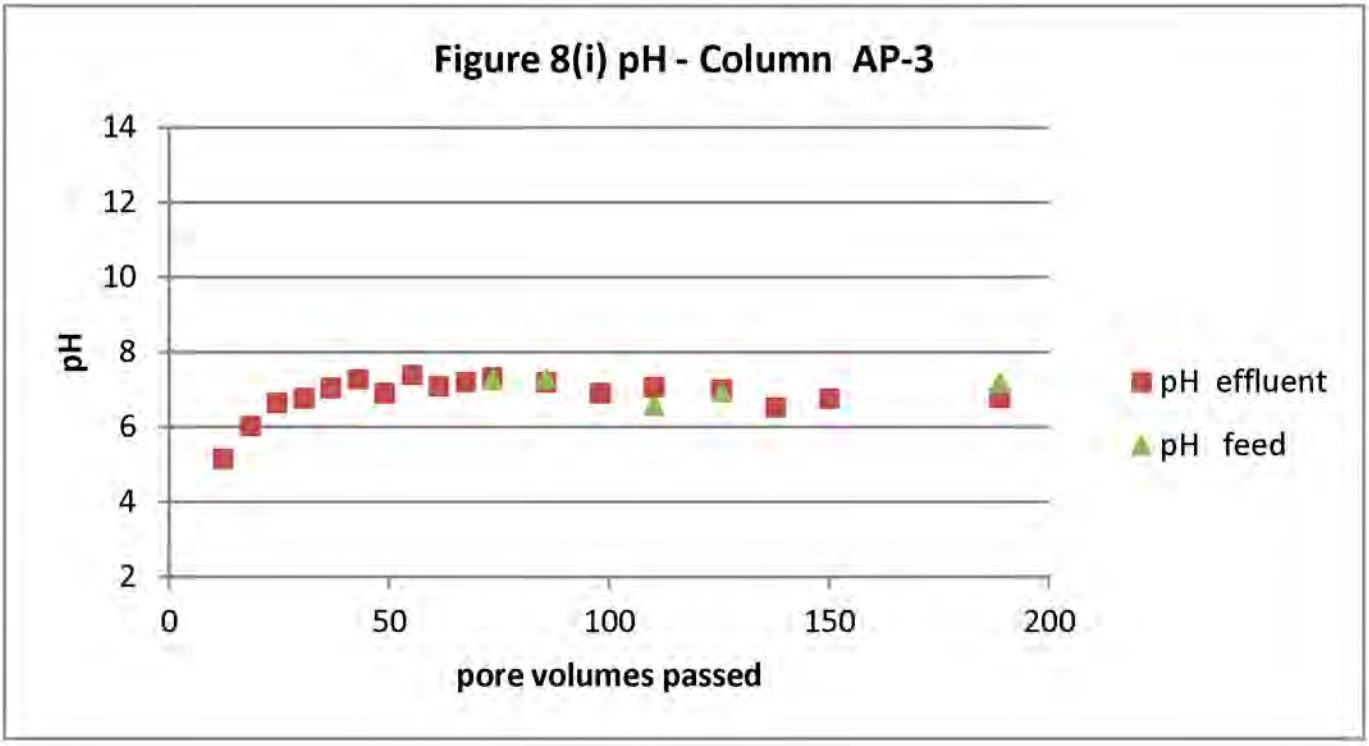


Figure 8(i) pH - Column AP-3
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

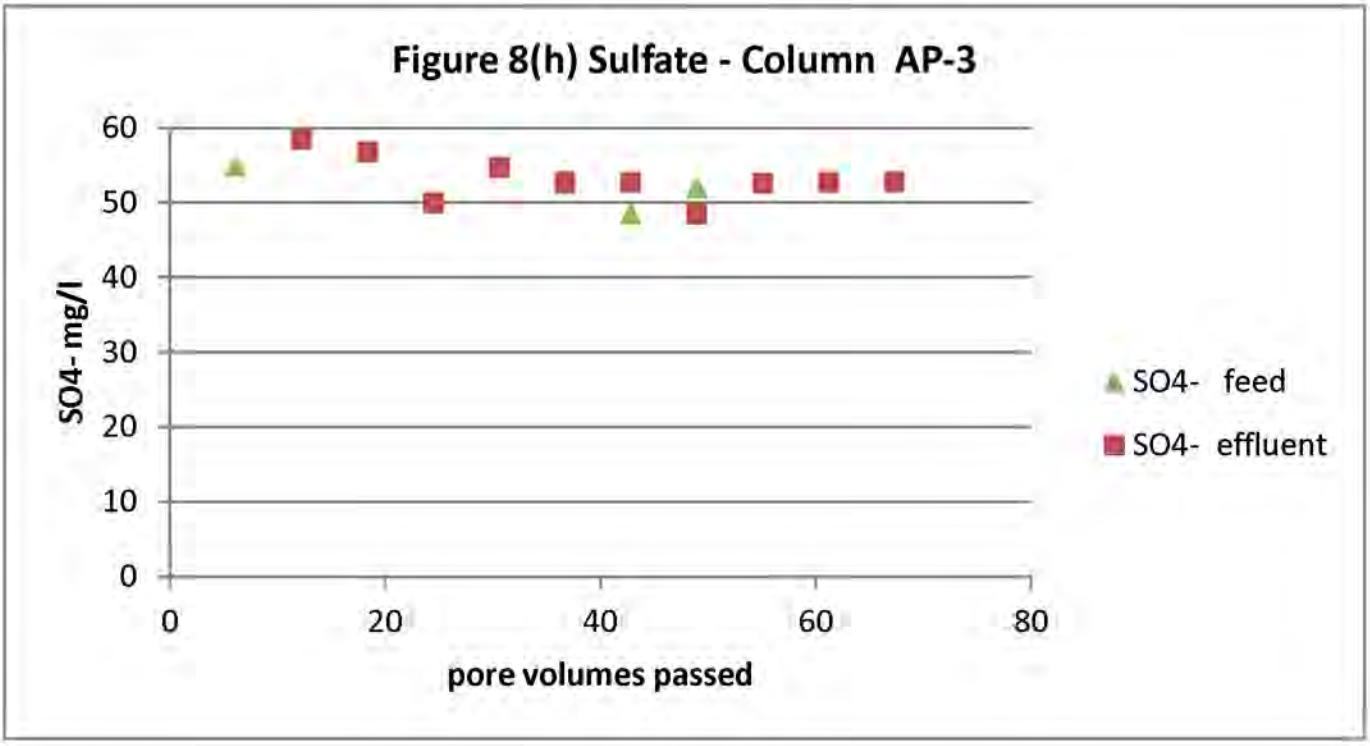


Figure 8(h) Sulfate - Column AP-3
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

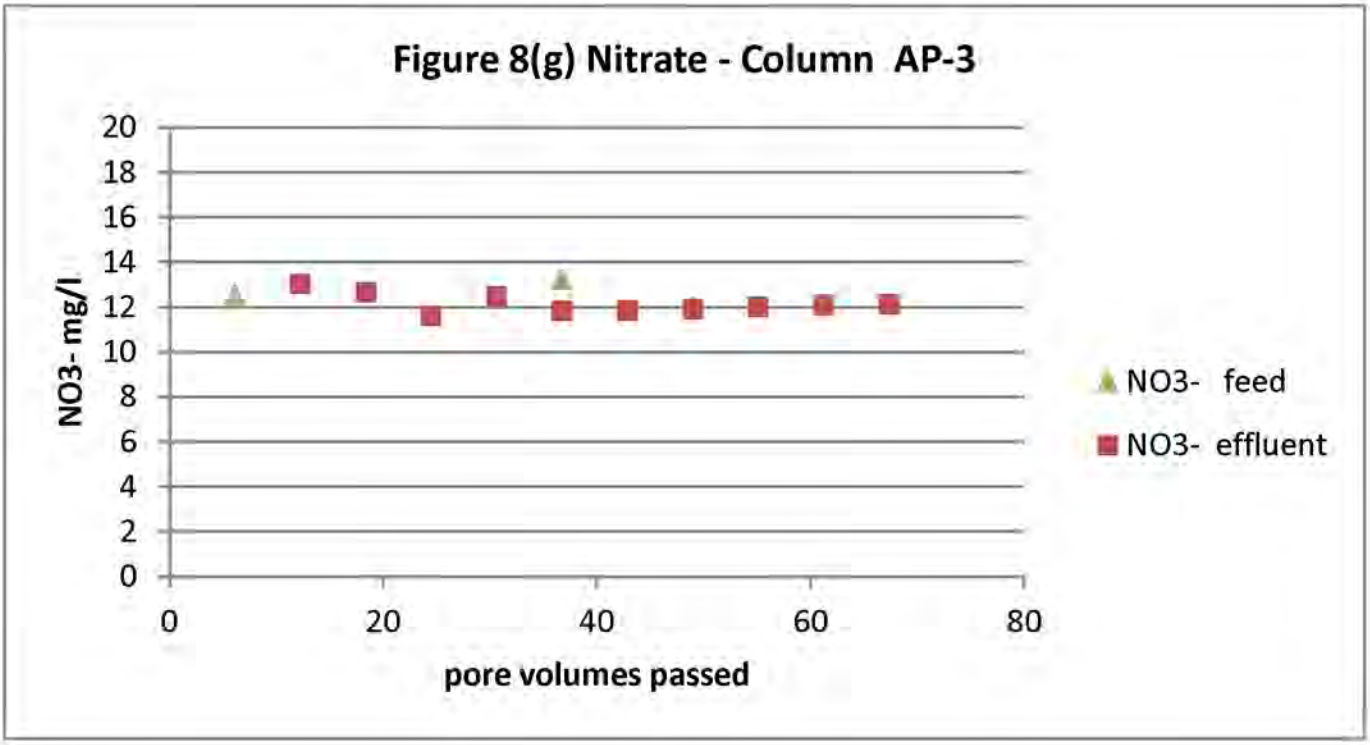


Figure 8(g) Nitrate - Column AP-3
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

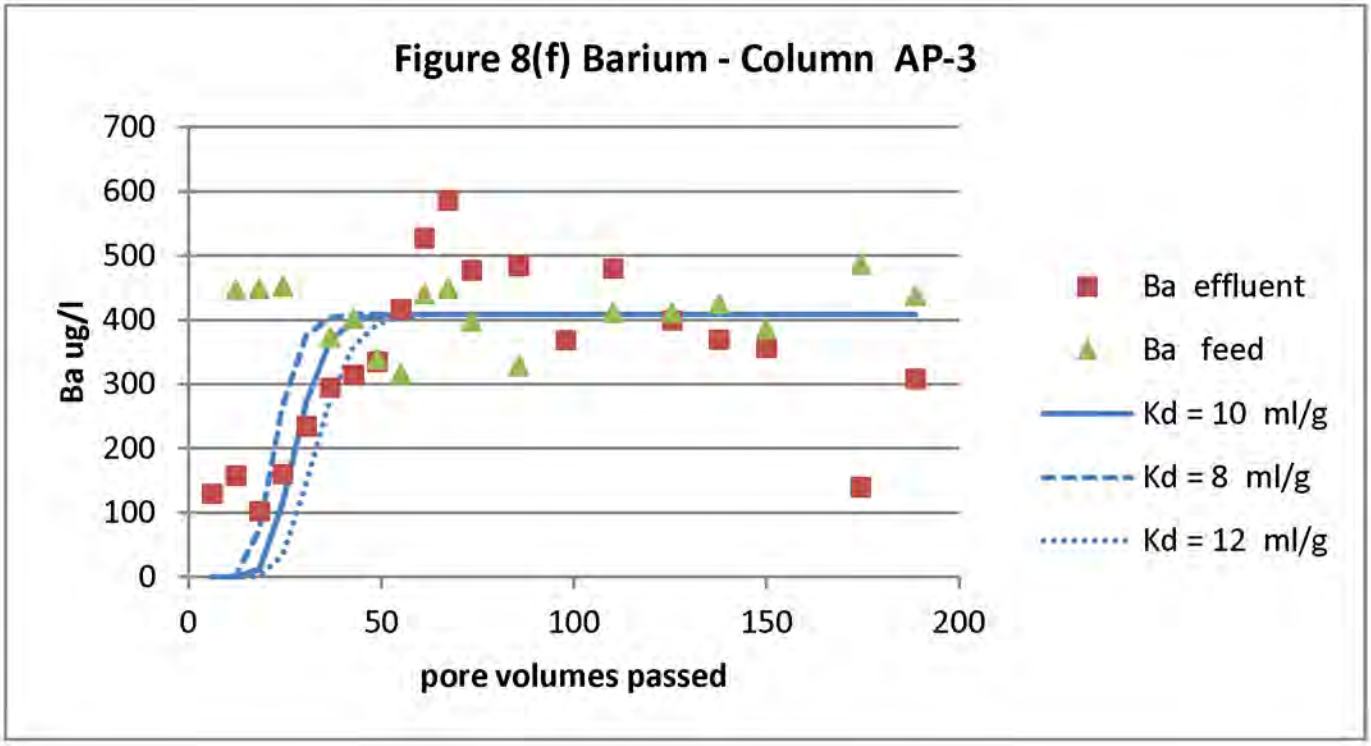


Figure 8(f) Barium - Column AP-3
700
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 10 ml/g
Kd = 8 ml/g
Kd = 12 ml/g

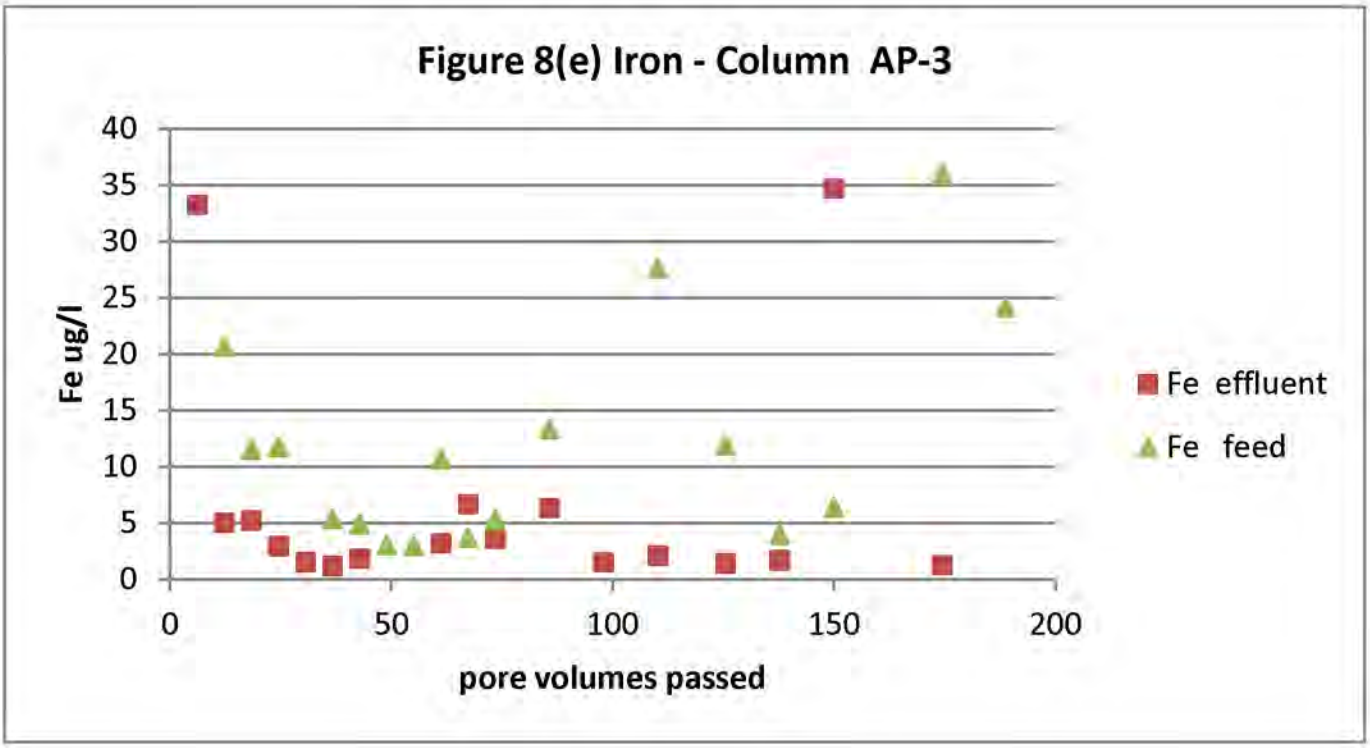


Figure 8(e) Iron - Column AP-3
Fe ug/l
40
35
30
25
20
15
10
5
0
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

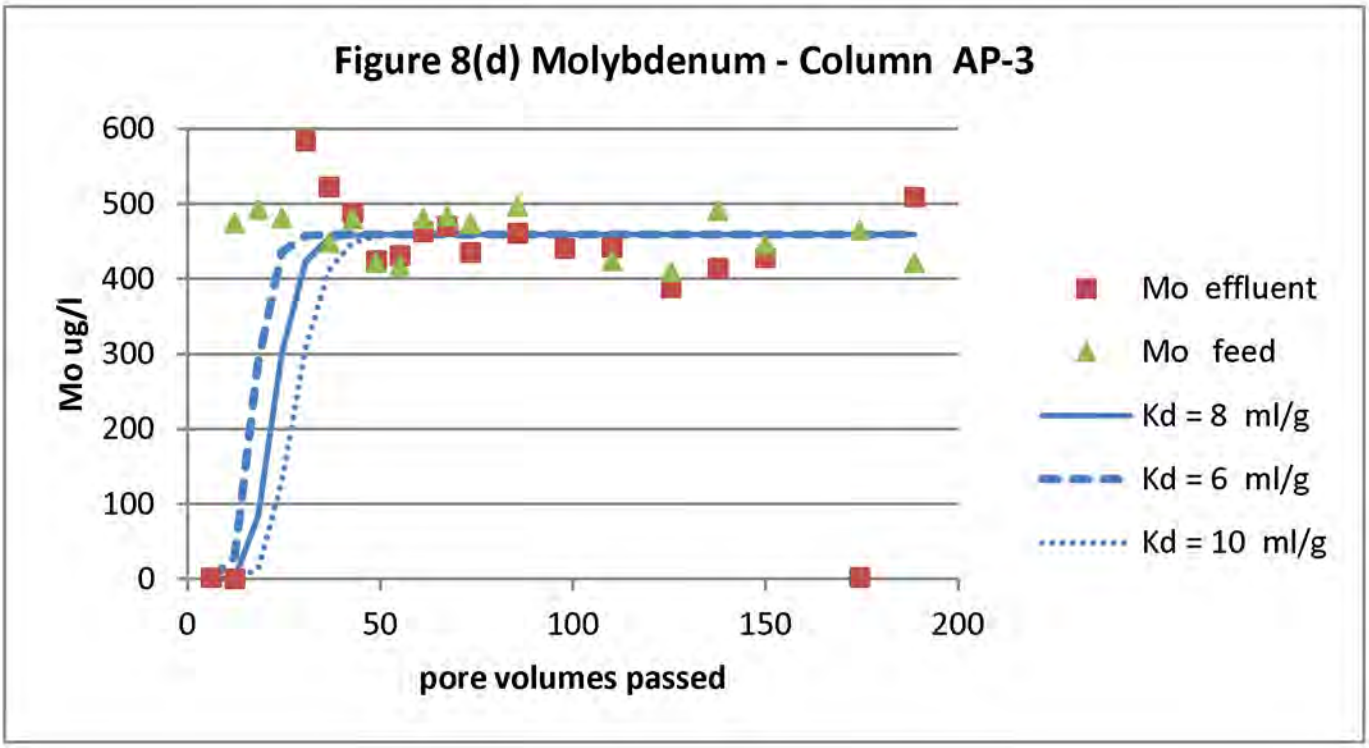


Figure 8(d) Molybdenum - Column AP-3
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 8 ml/g
Kd = 6 ml/g
Kd = 10 ml/g

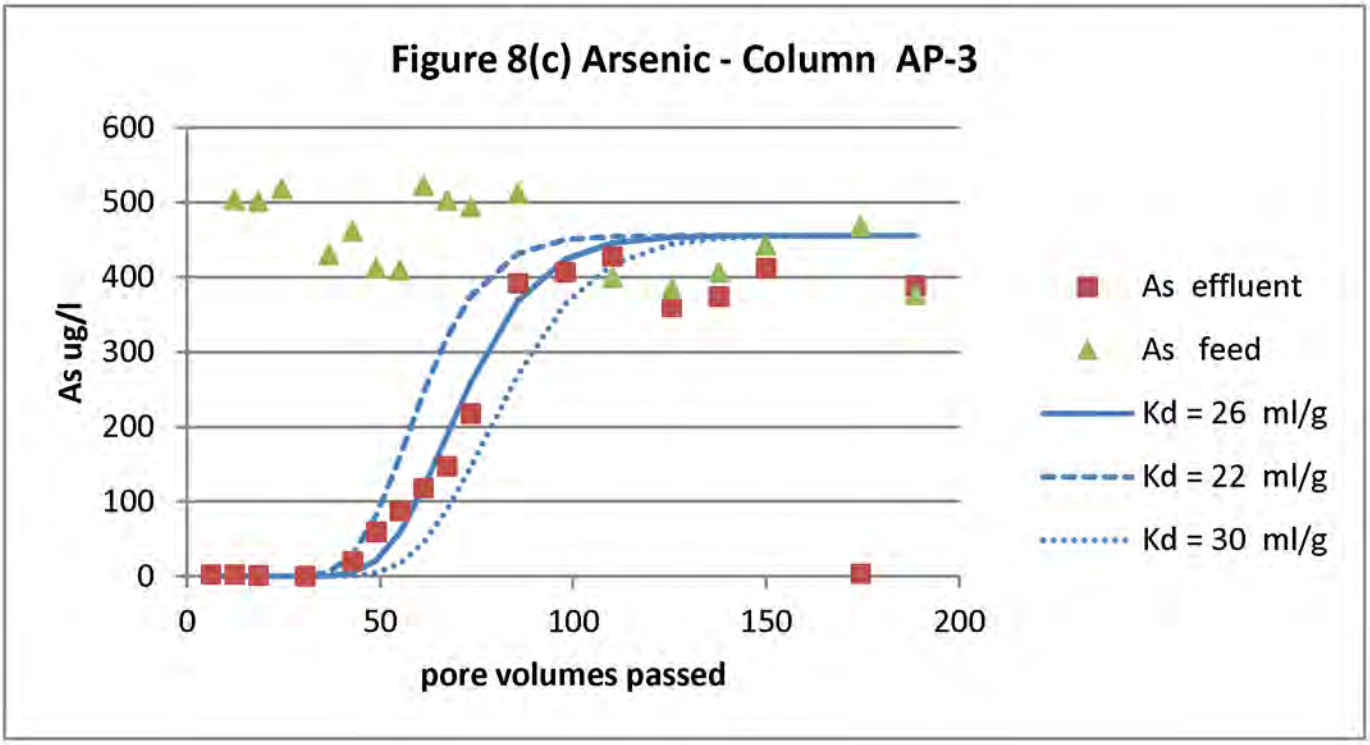


Figure 8(c) Arsenic - Column AP-3
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 26 ml/g
Kd = 22 ml/g
Kd = 30 ml/g

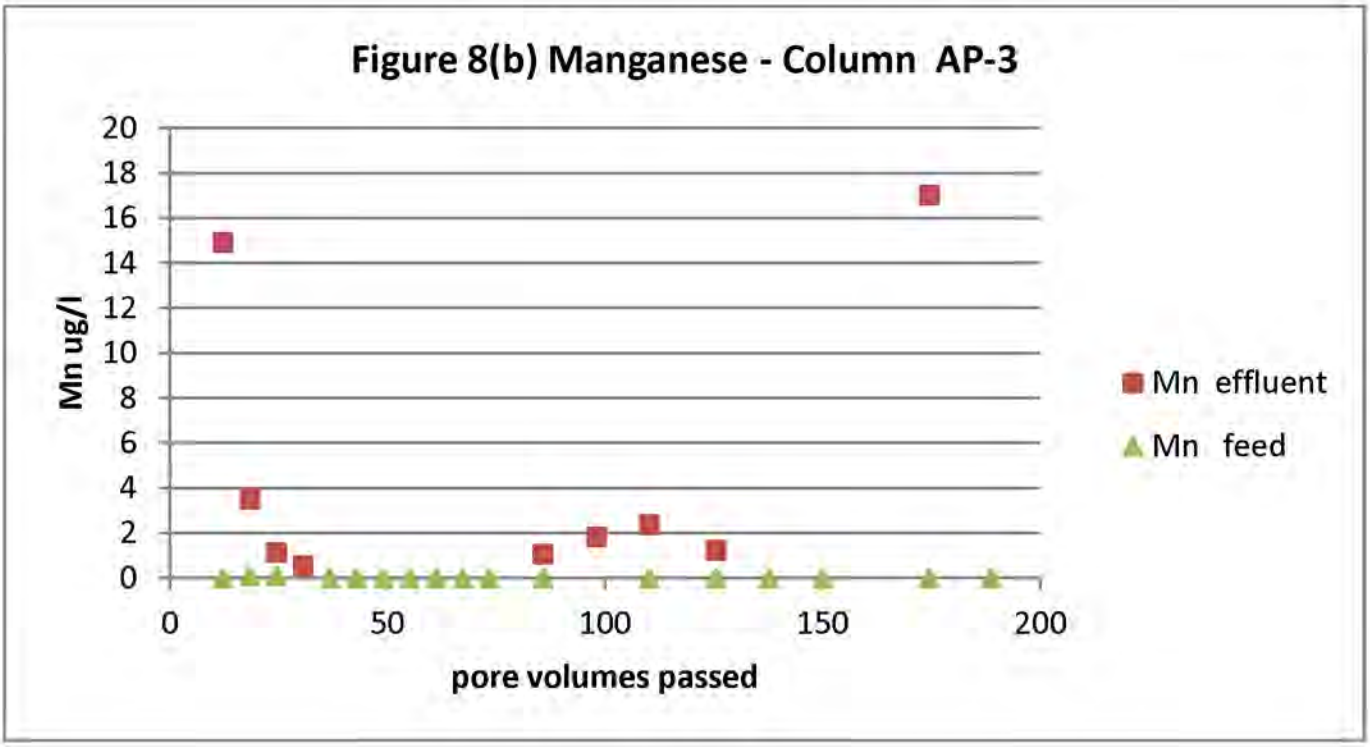


Figure 8(b) Manganese - Column AP-3
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

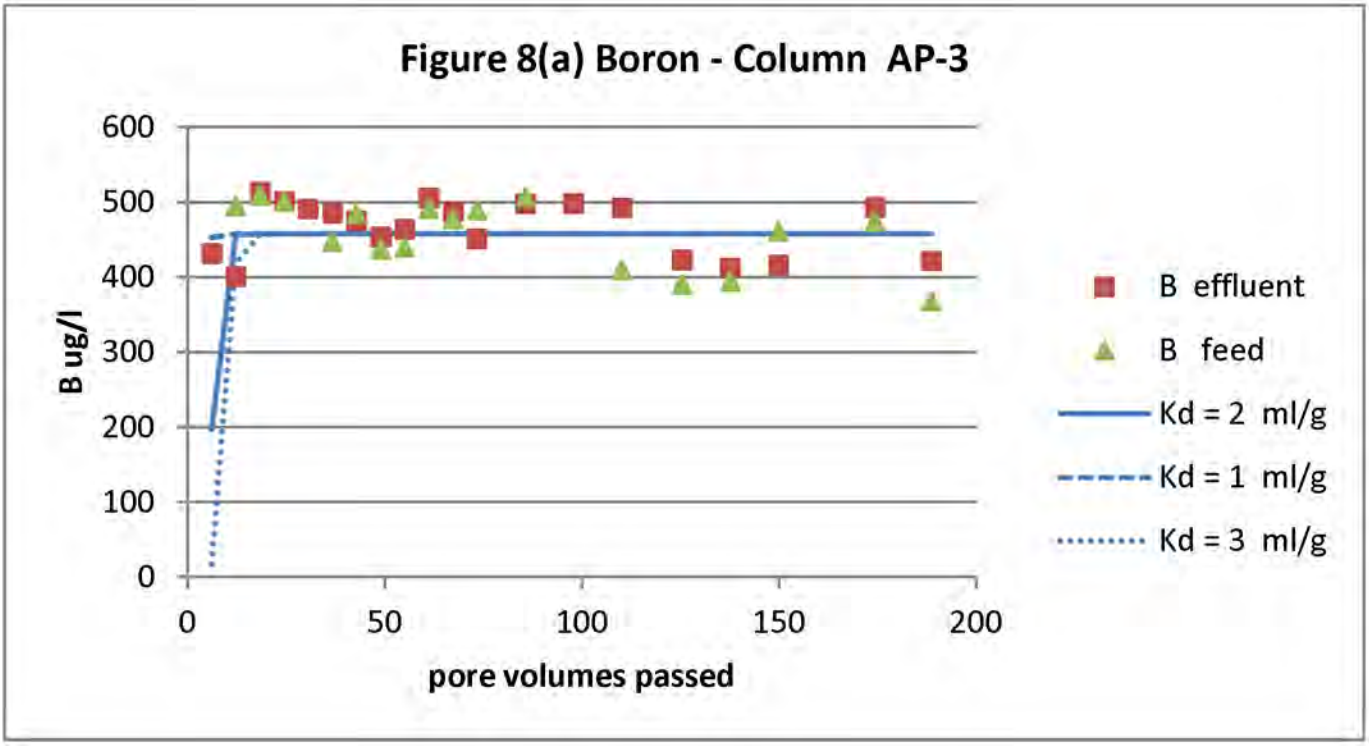


Figure 8(a) Boron - Column AP-3
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 2 ml/g
Kd = 1 ml/g
Kd = 3 ml/g

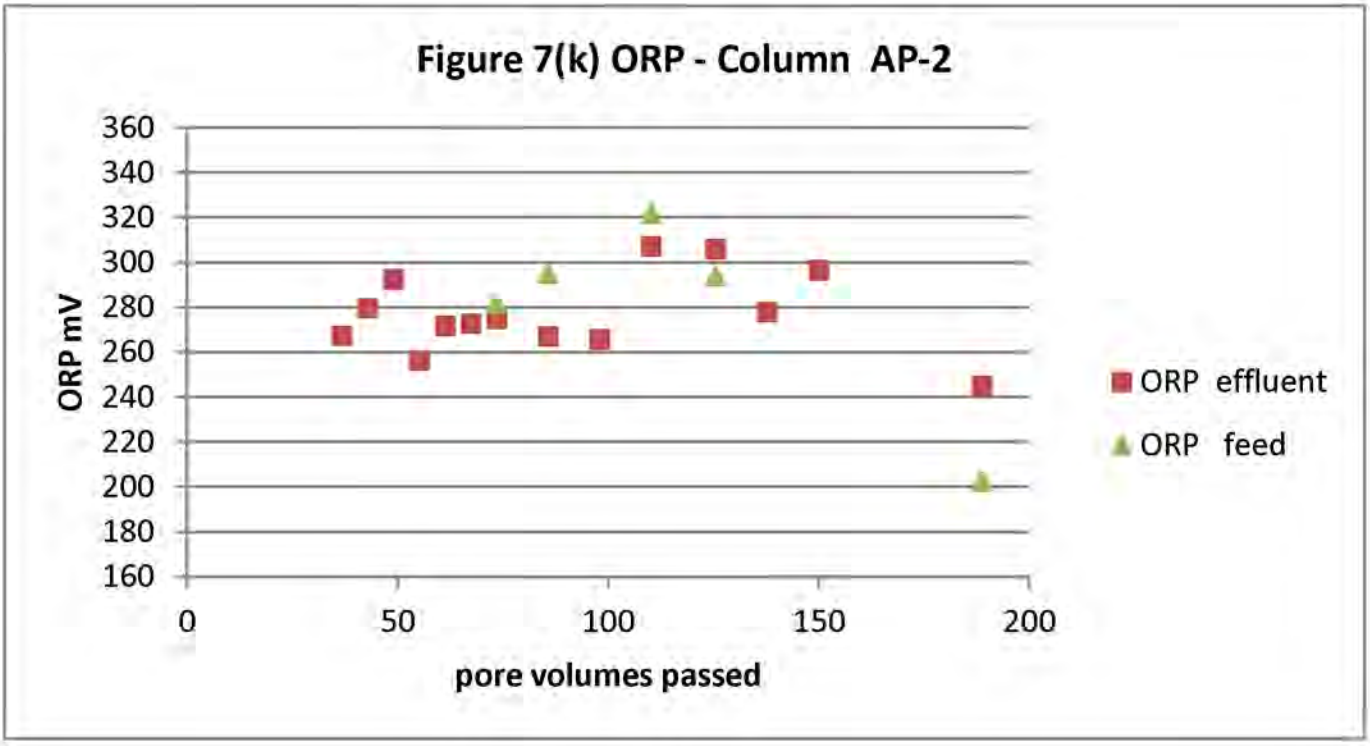


Figure 7(k) ORP - Column AP-2
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

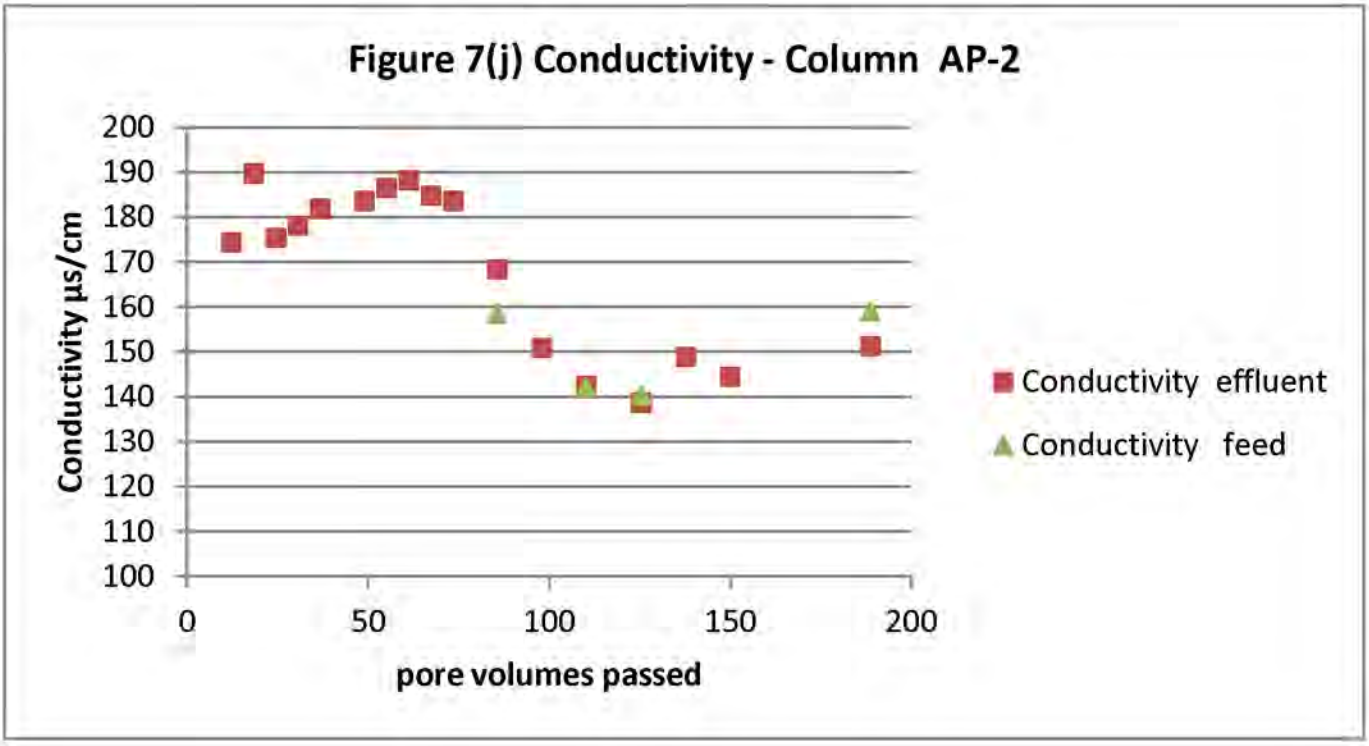


Figure 7(j) Conductivity - Column AP-2
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

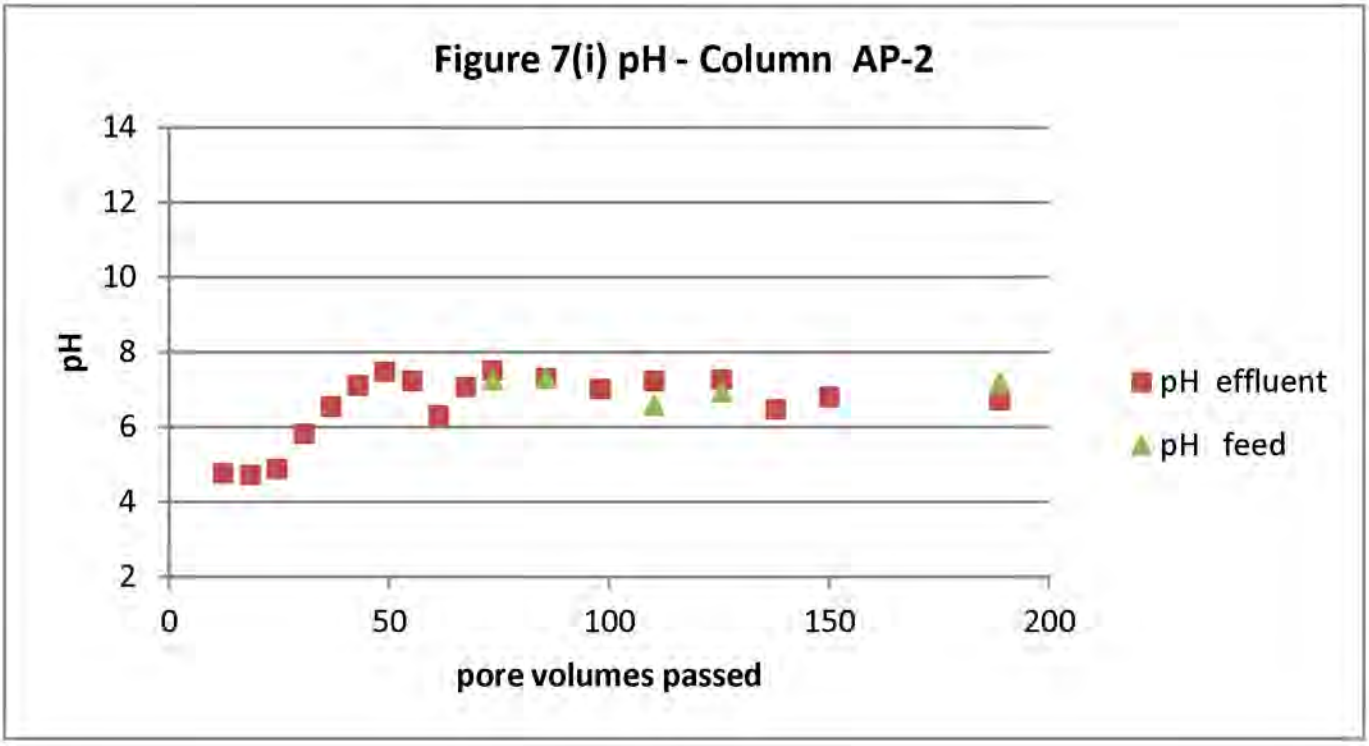


Figure 7(i) pH - Column AP-2
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

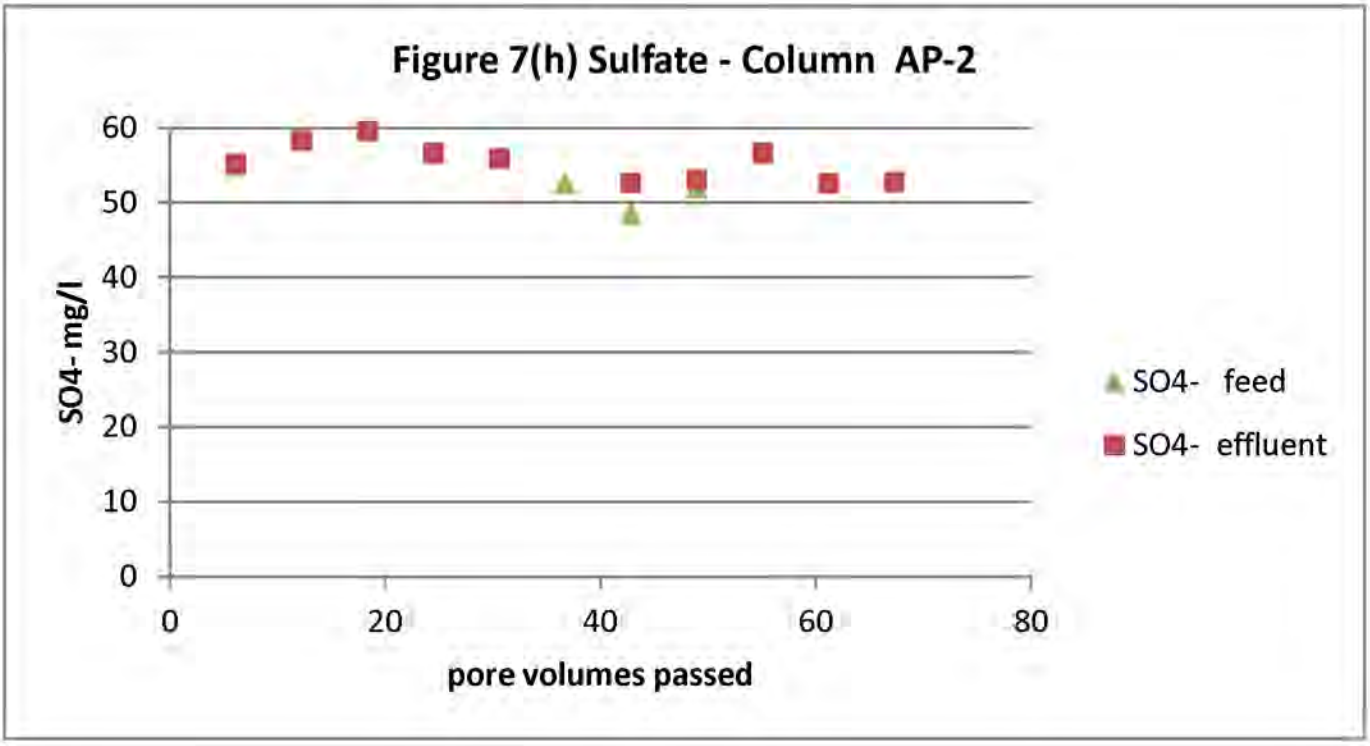


Figure 7(h) Sulfate - Column AP-2
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

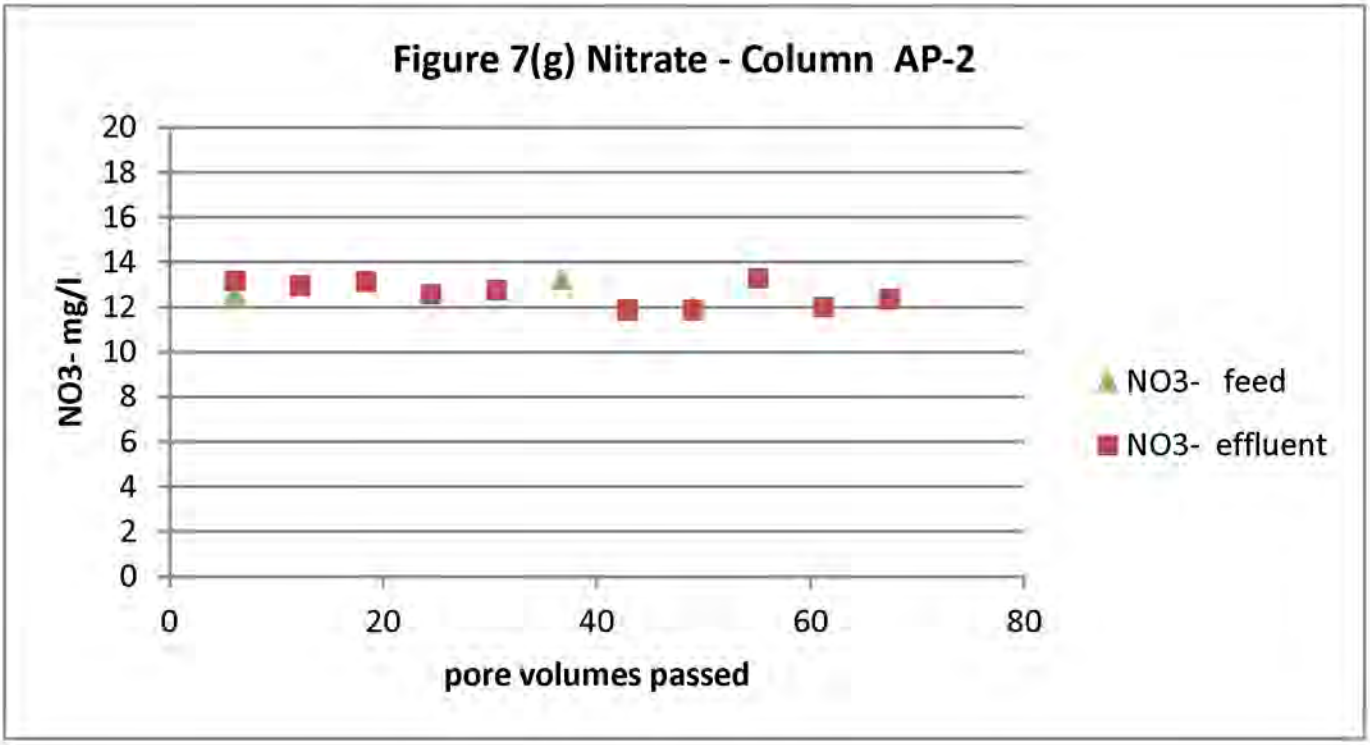


Figure 7(g) Nitrate - Column AP-2
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

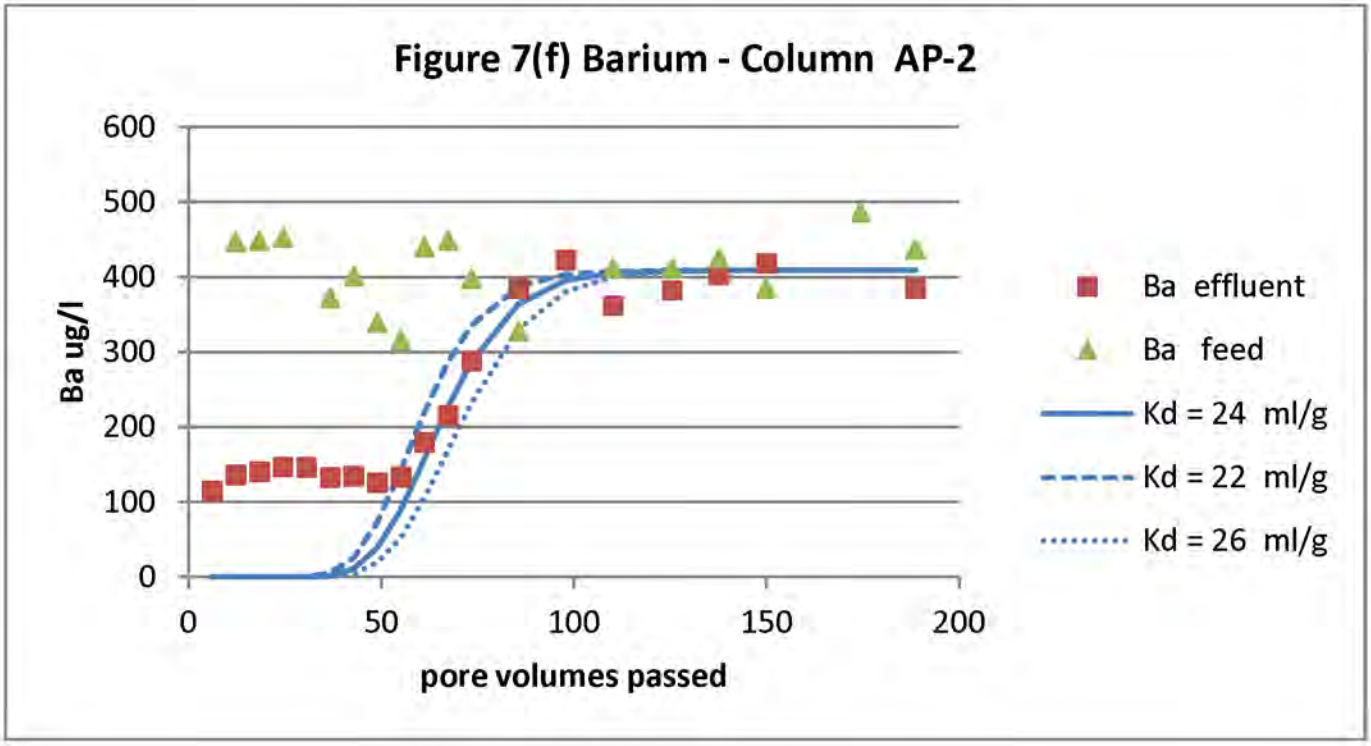


Figure 7(f) Barium - Column AP-2
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 24 ml/g
Kd = 22 ml/g
Kd = 26 ml/g

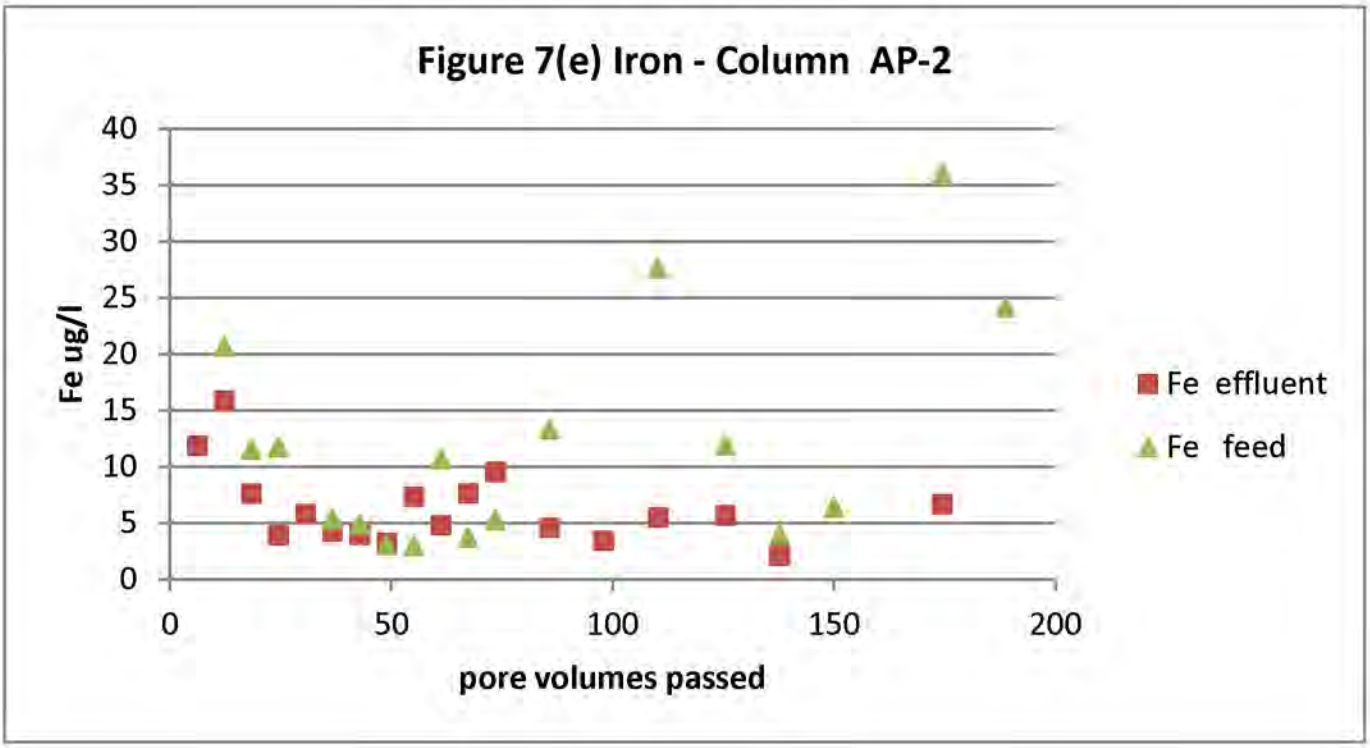


Figure 7(e) Iron - Column AP-2
Fe ug/l
40
35
30
25
20
15
10
5
0
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

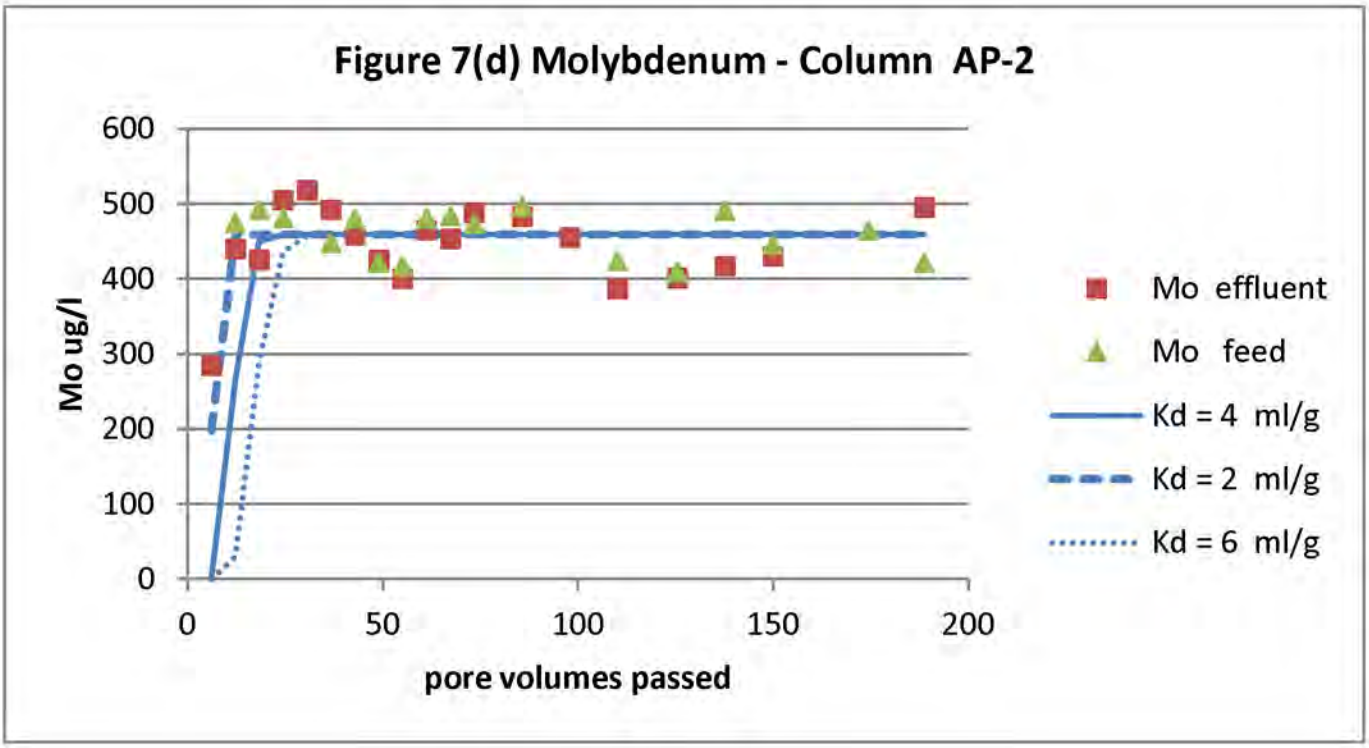


Figure 7(d) Molybdenum - Column AP-2
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 4 ml/g
Kd = 2 ml/g
Kd = 6 ml/g

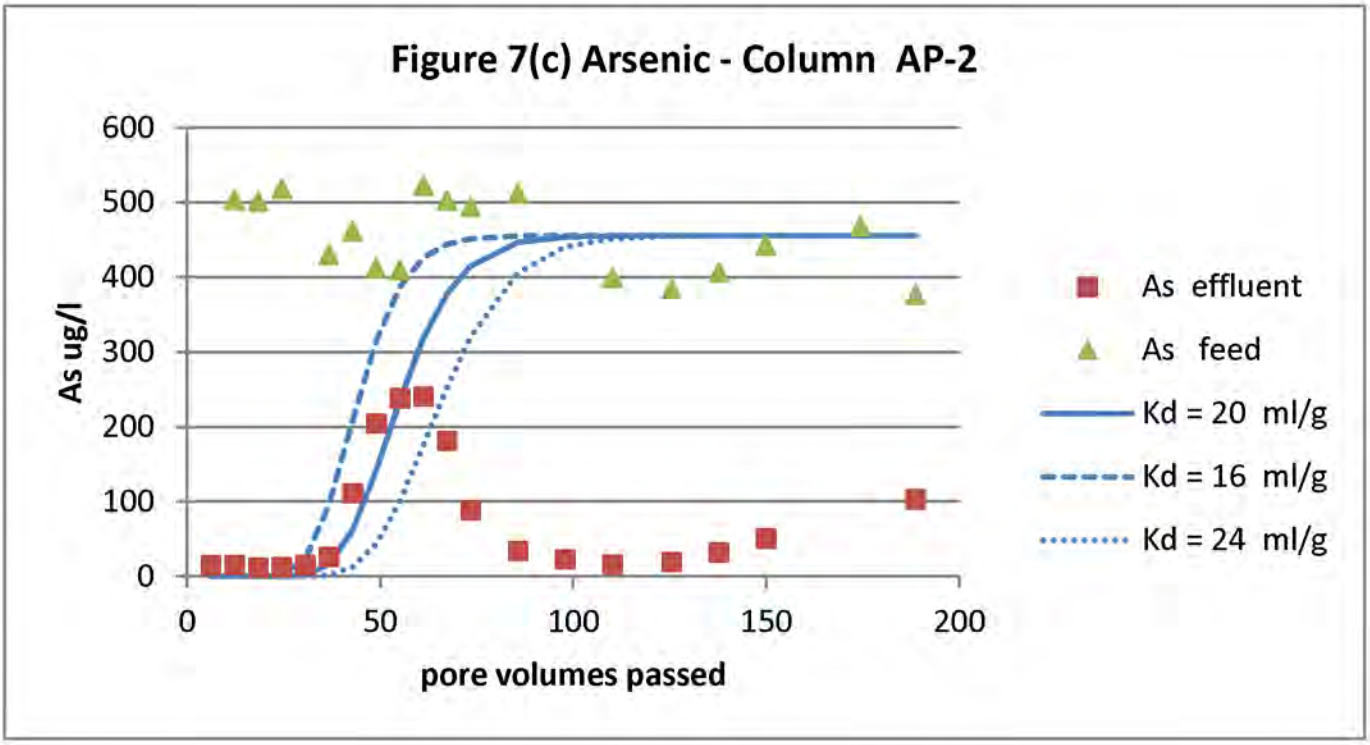


Figure 7(c) Arsenic - Column AP-2
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 20 ml/g
Kd = 16 ml/g
Kd = 24 ml/g

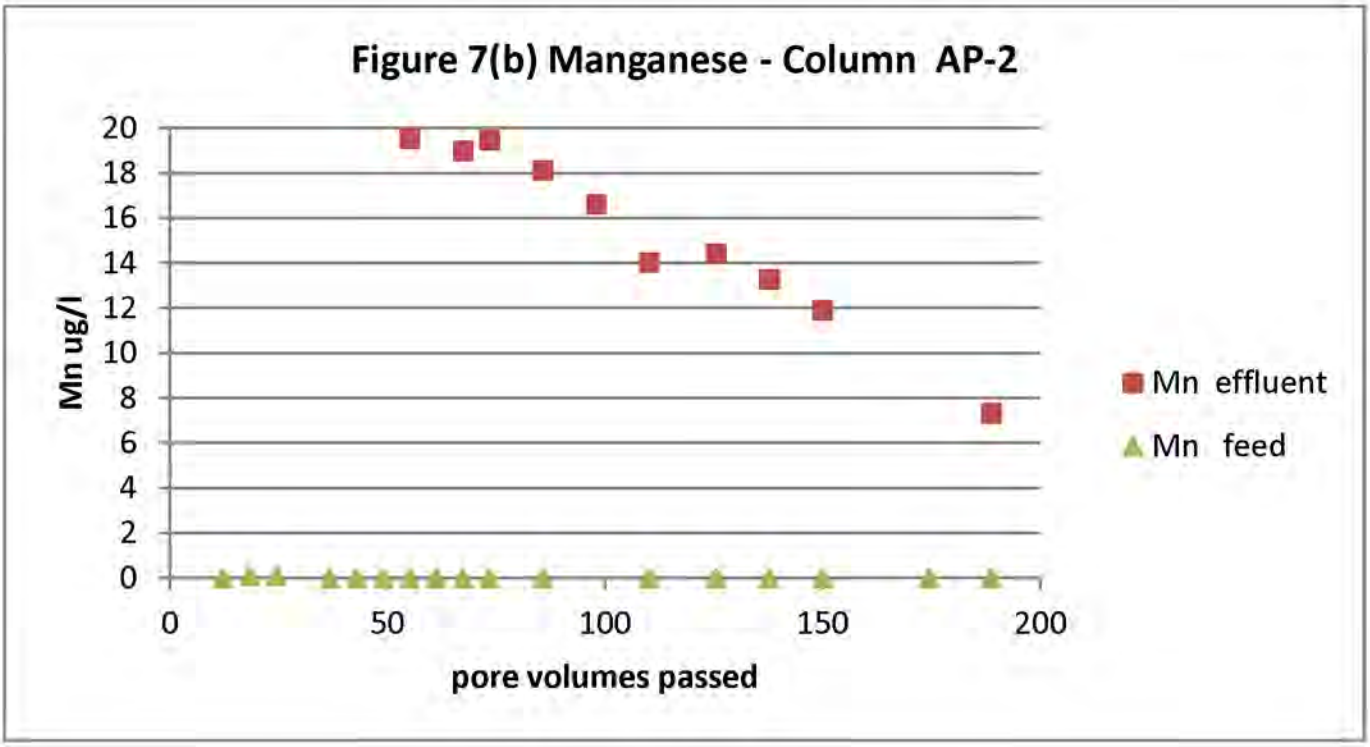


Figure 7(b) Manganese - Column AP-2
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

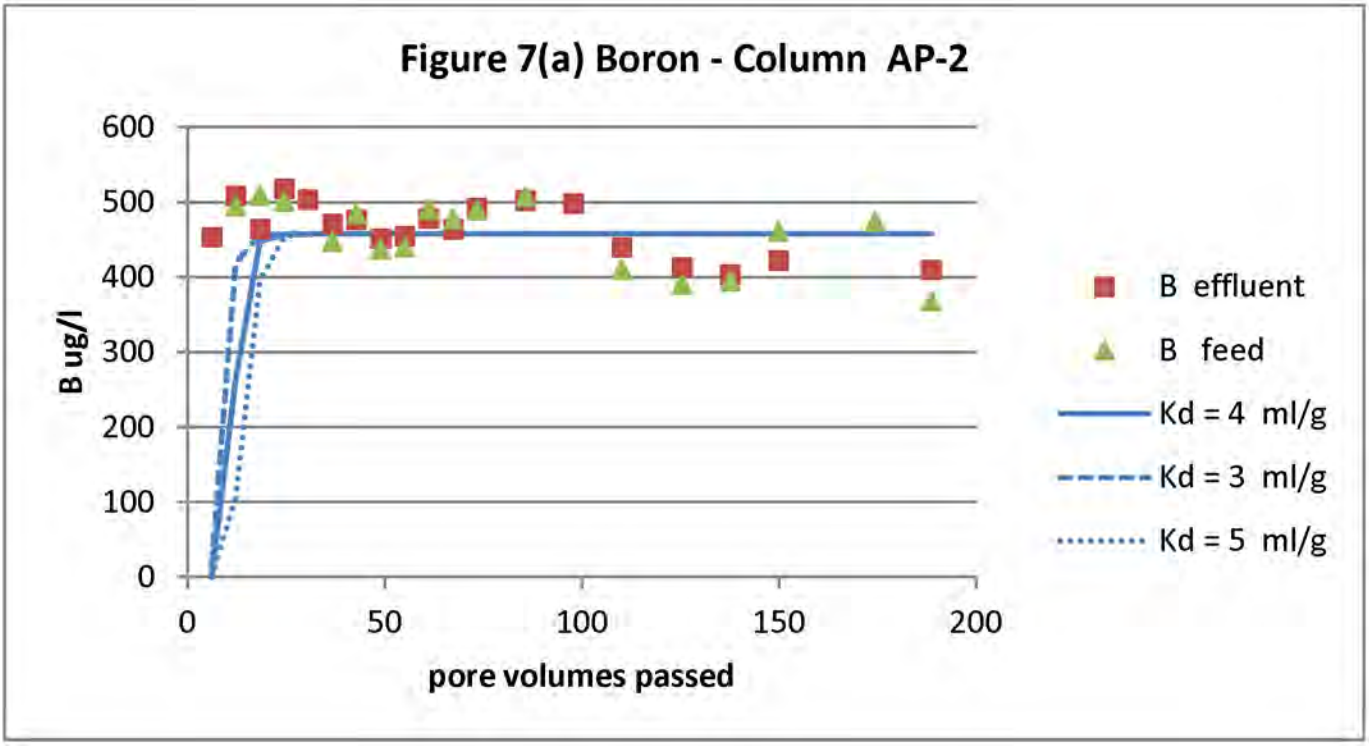


Figure 7(a) Boron - Column AP-2
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 4 ml/g
Kd = 3 ml/g
Kd = 5 ml/g

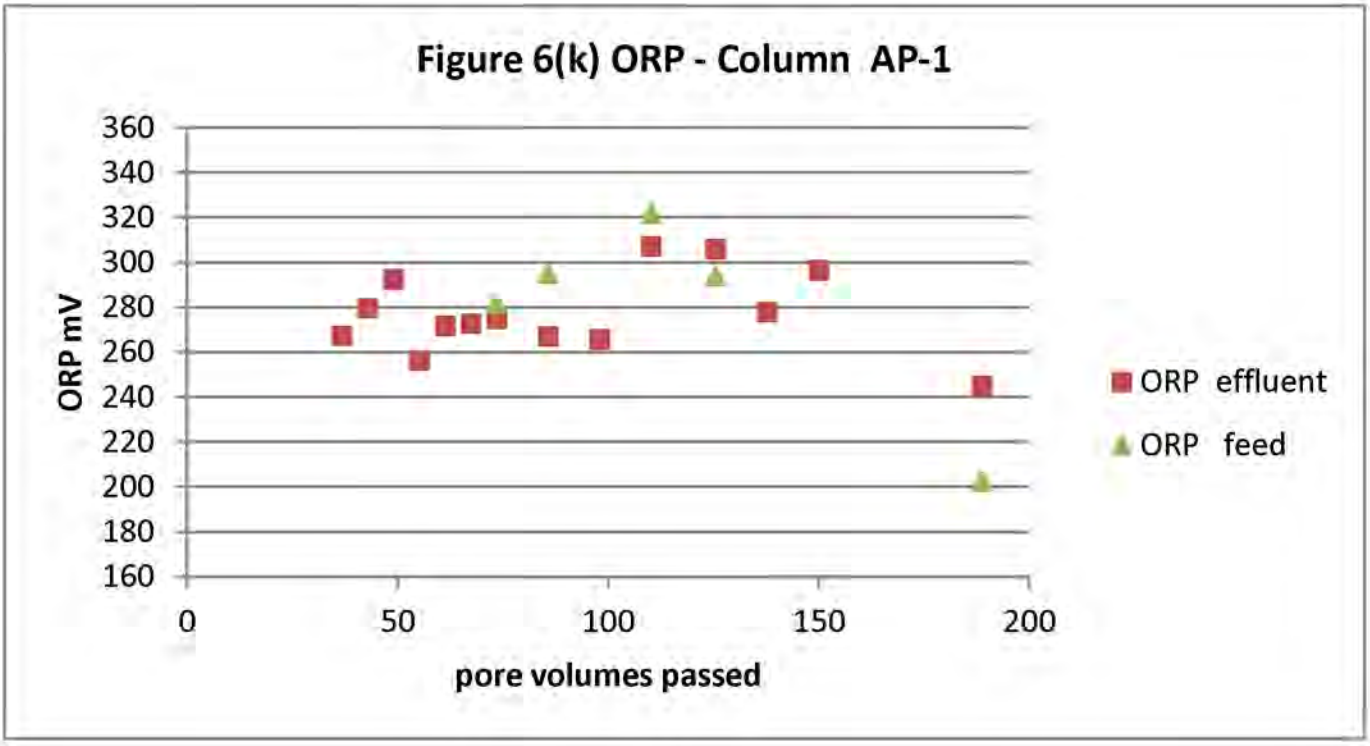


Figure 6(k) ORP - Column AP-1
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

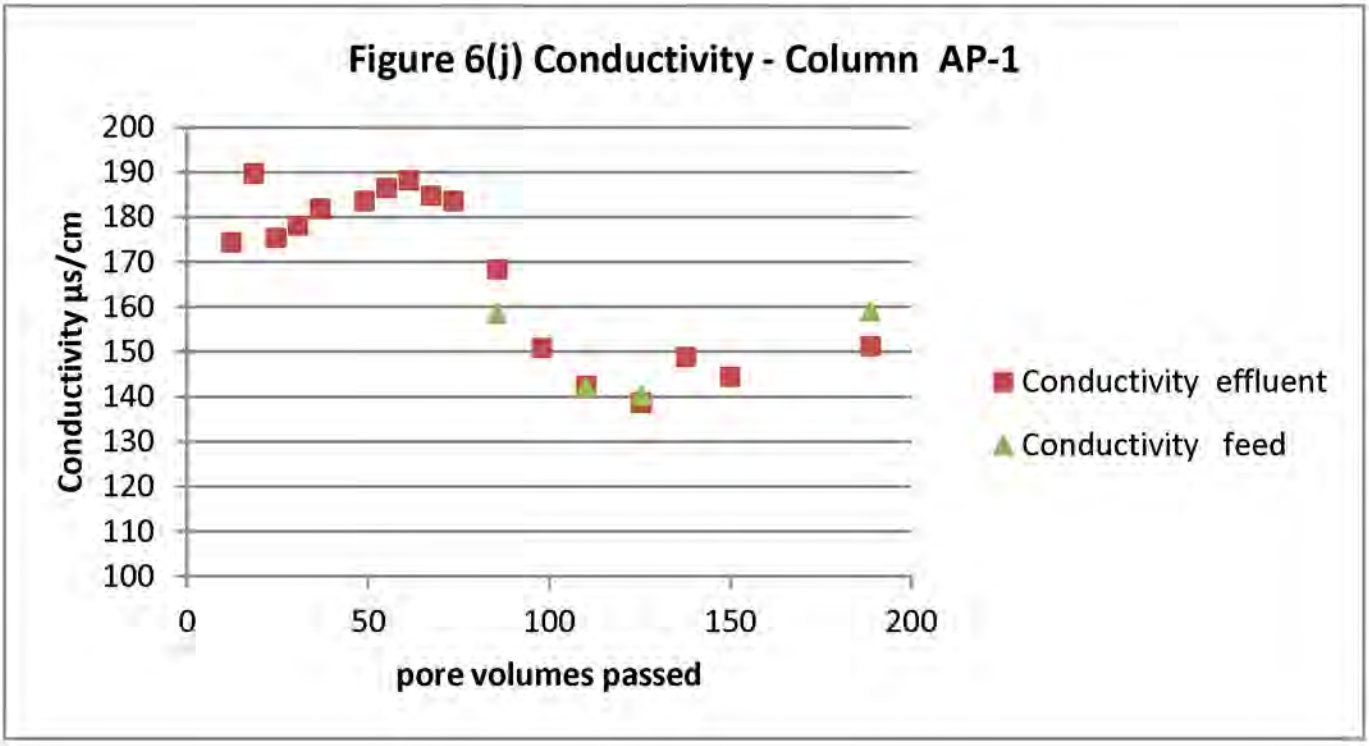


Figure 6(j) Conductivity - Column AP-1
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

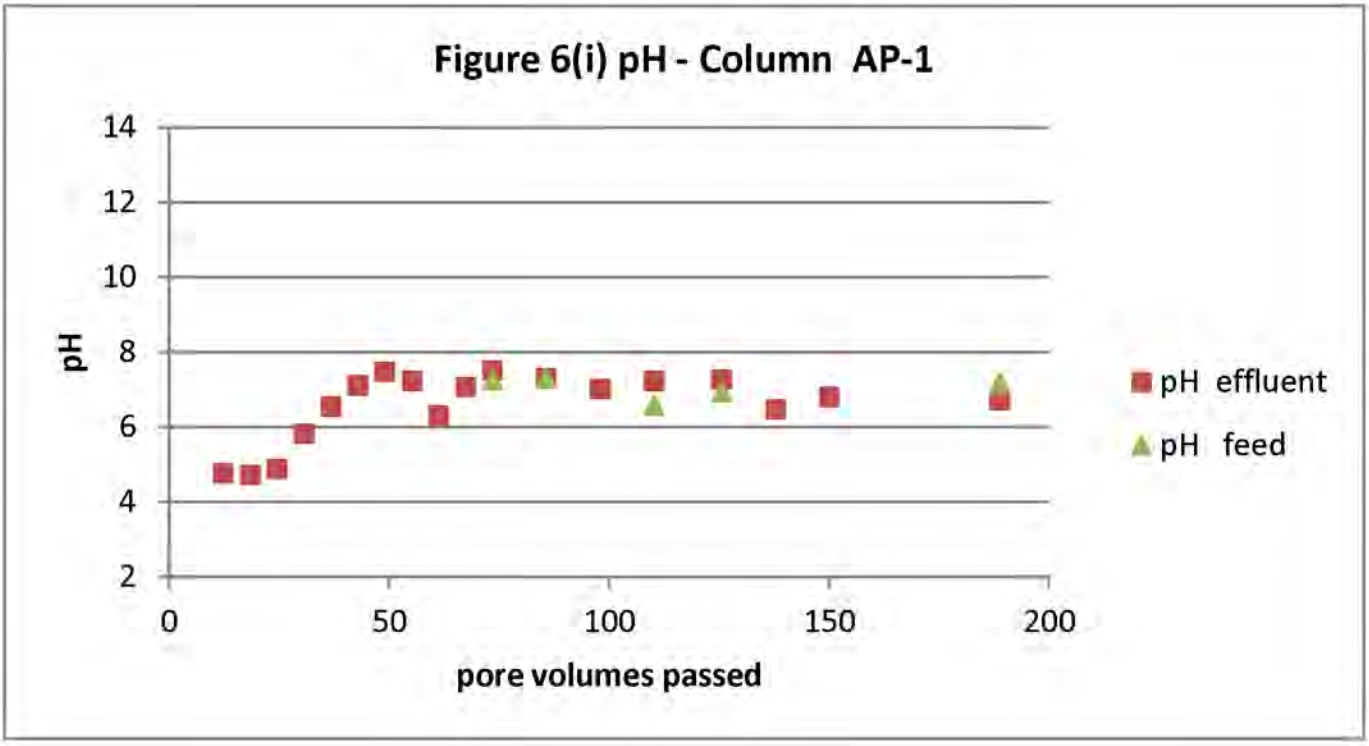


Figure 6(i) pH - Column AP-1
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

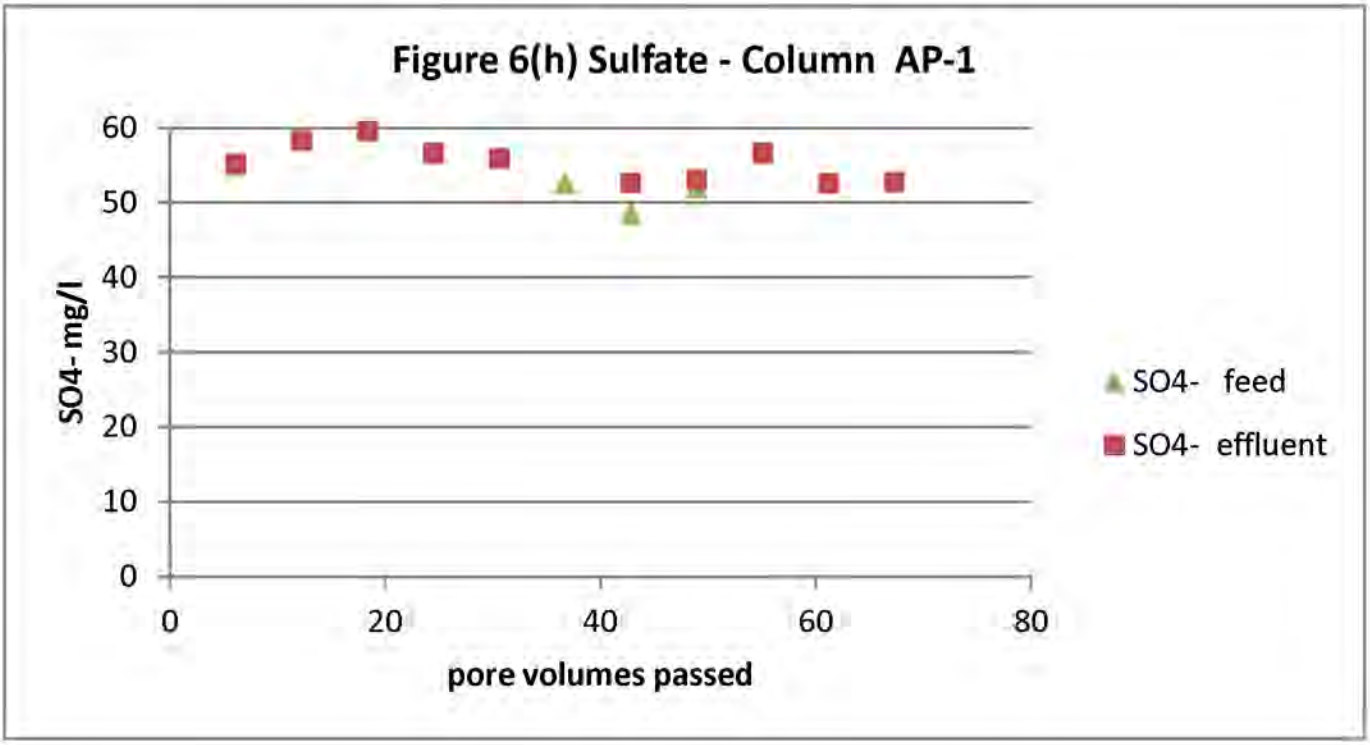


Figure 6(h) Sulfate - Column AP-1
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

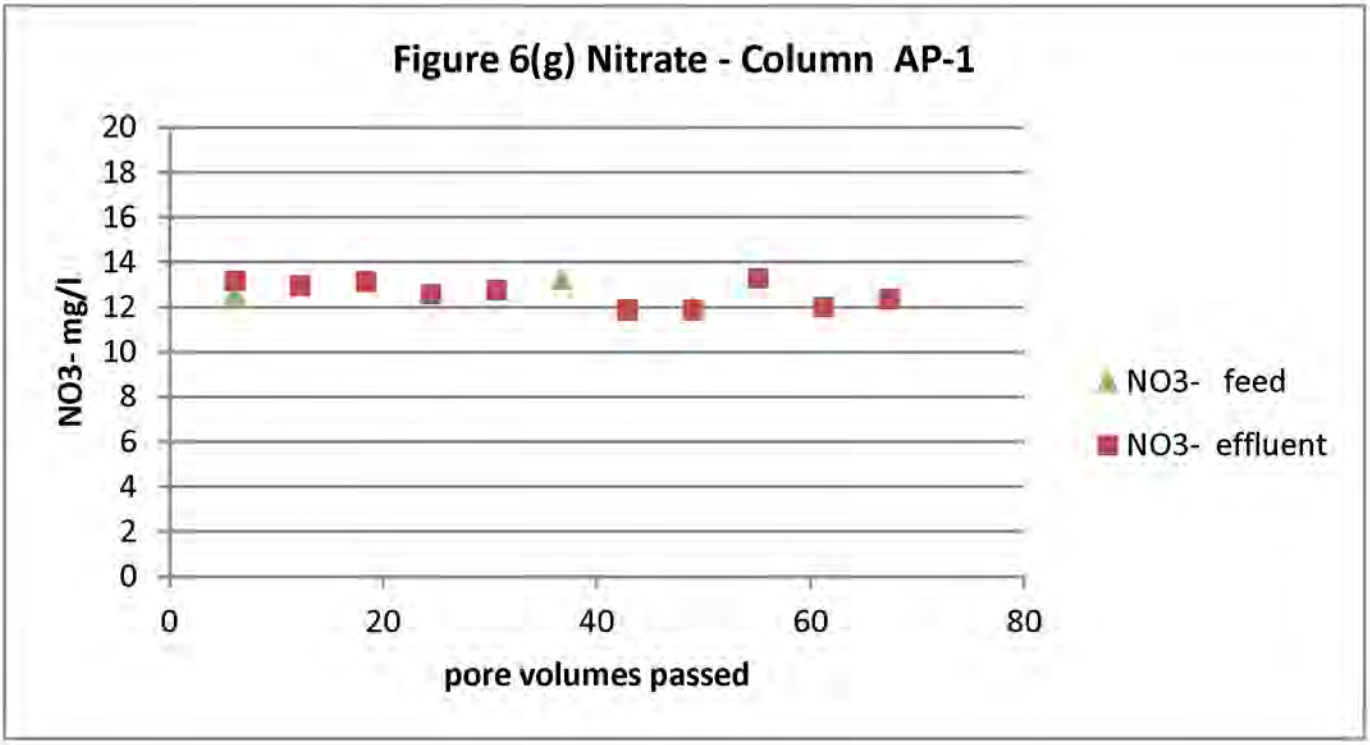


Figure 6(g) Nitrate - Column AP-1
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

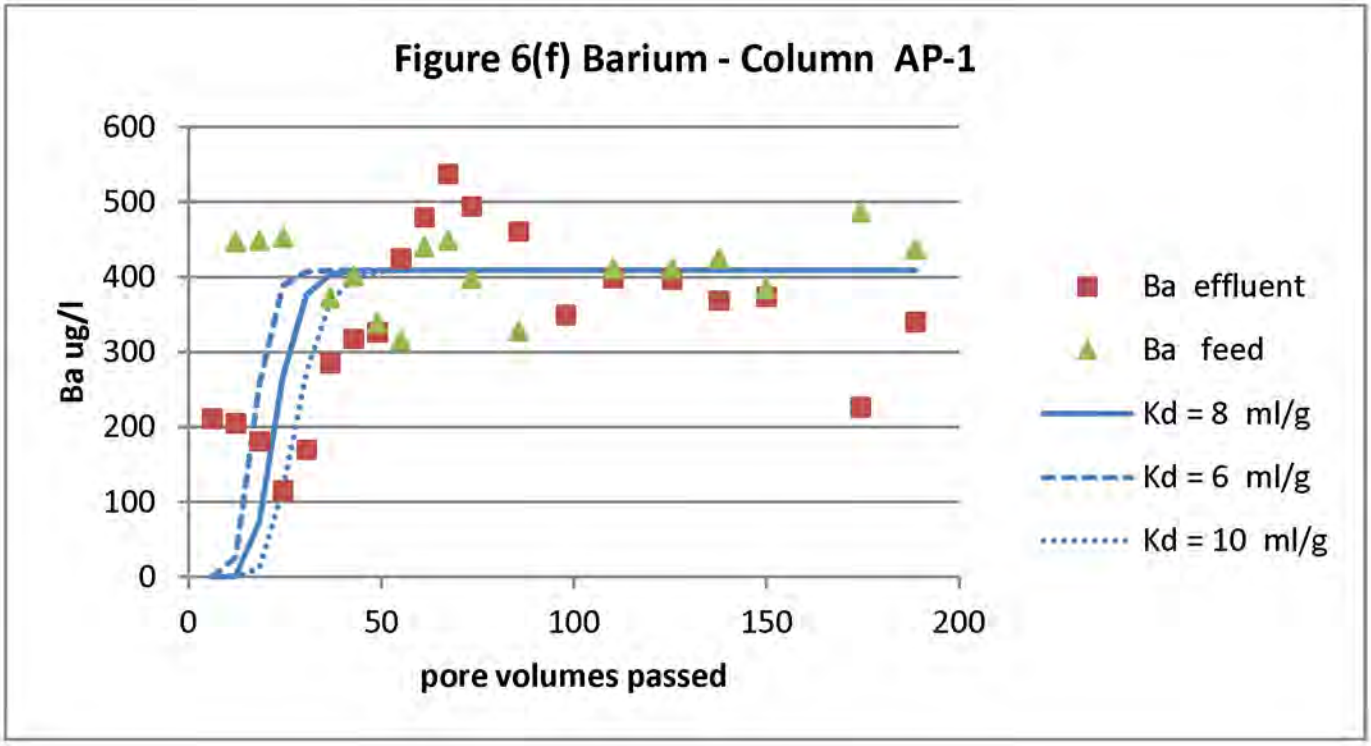


Figure 6(f) Barium - Column AP-1
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 8 ml/g
Kd = 6 ml/g
Kd = 10 ml/g

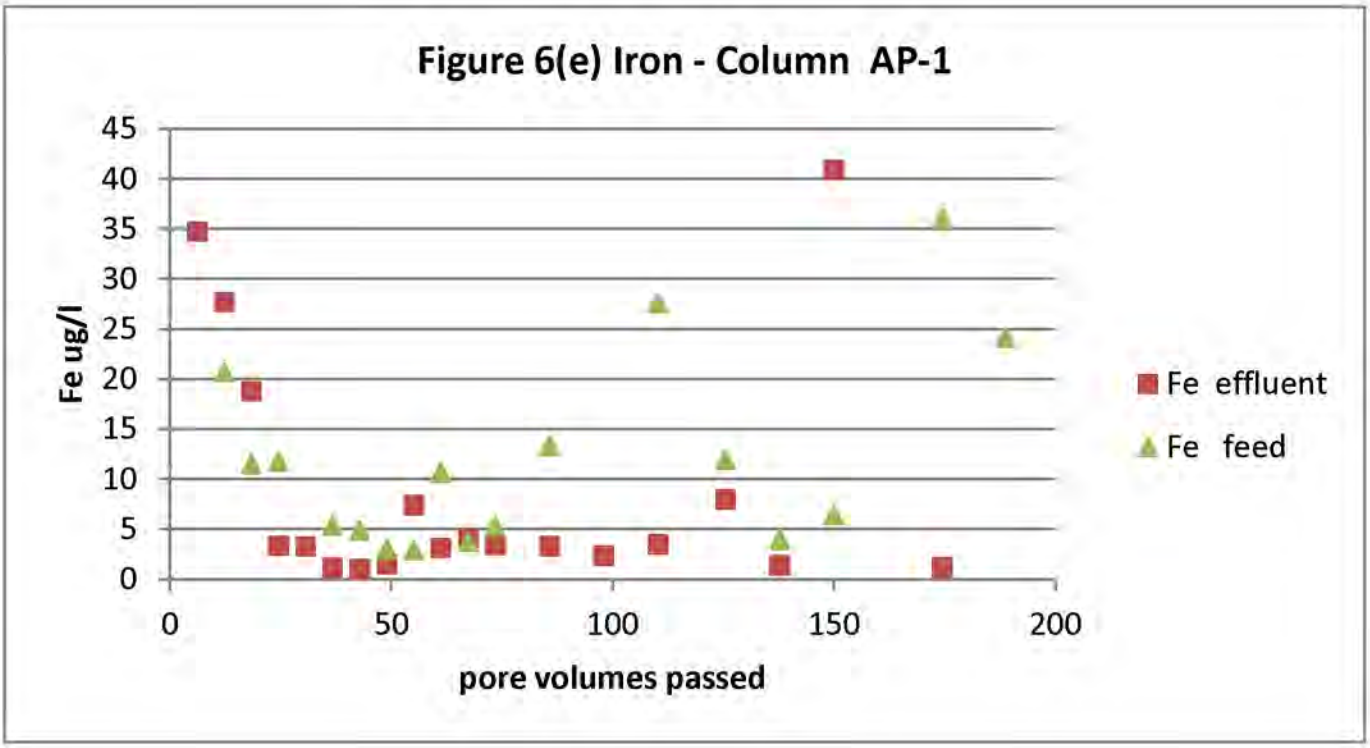


Figure 6(e) Iron - Column AP-1
45
40
35
30
25
20
15
10
5
0
Fe ug/l
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

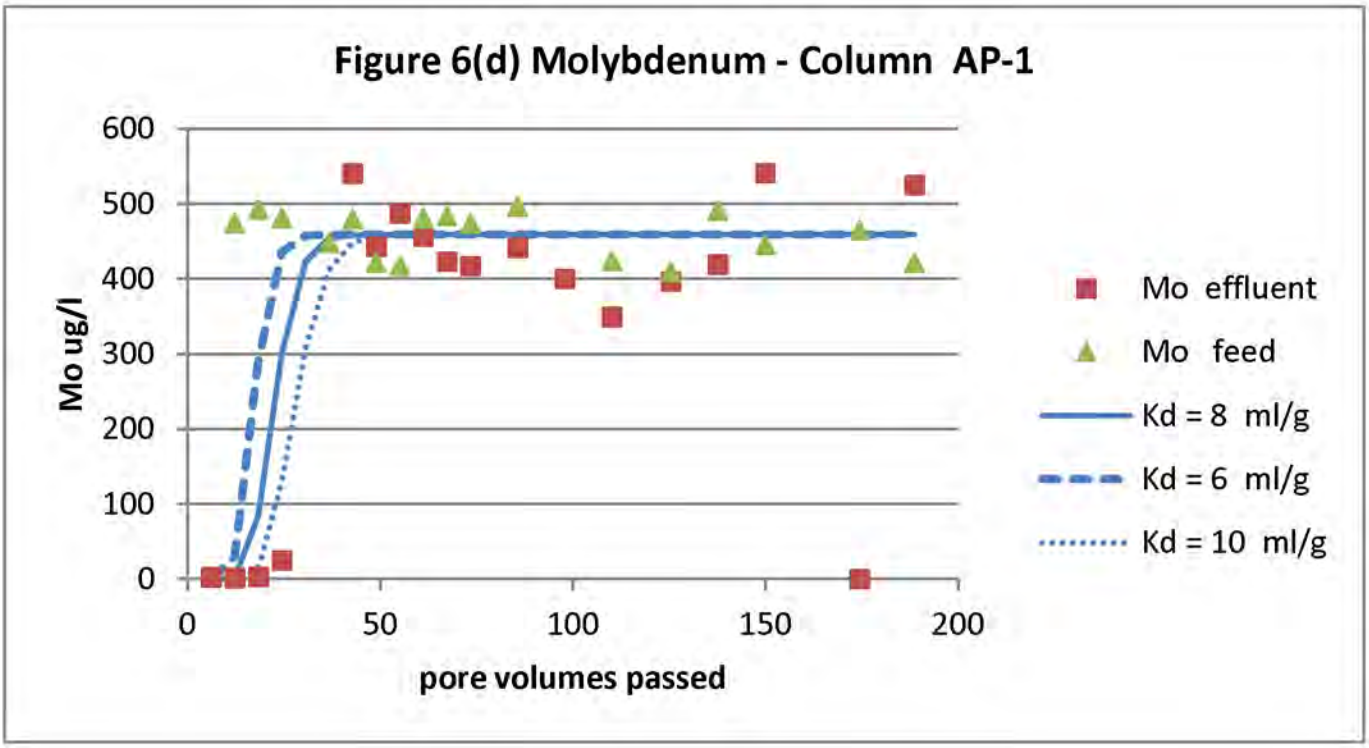


Figure 6(d) Molybdenum - Column AP-1
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 8 ml/g
Kd = 6 ml/g
Kd = 10 ml/g

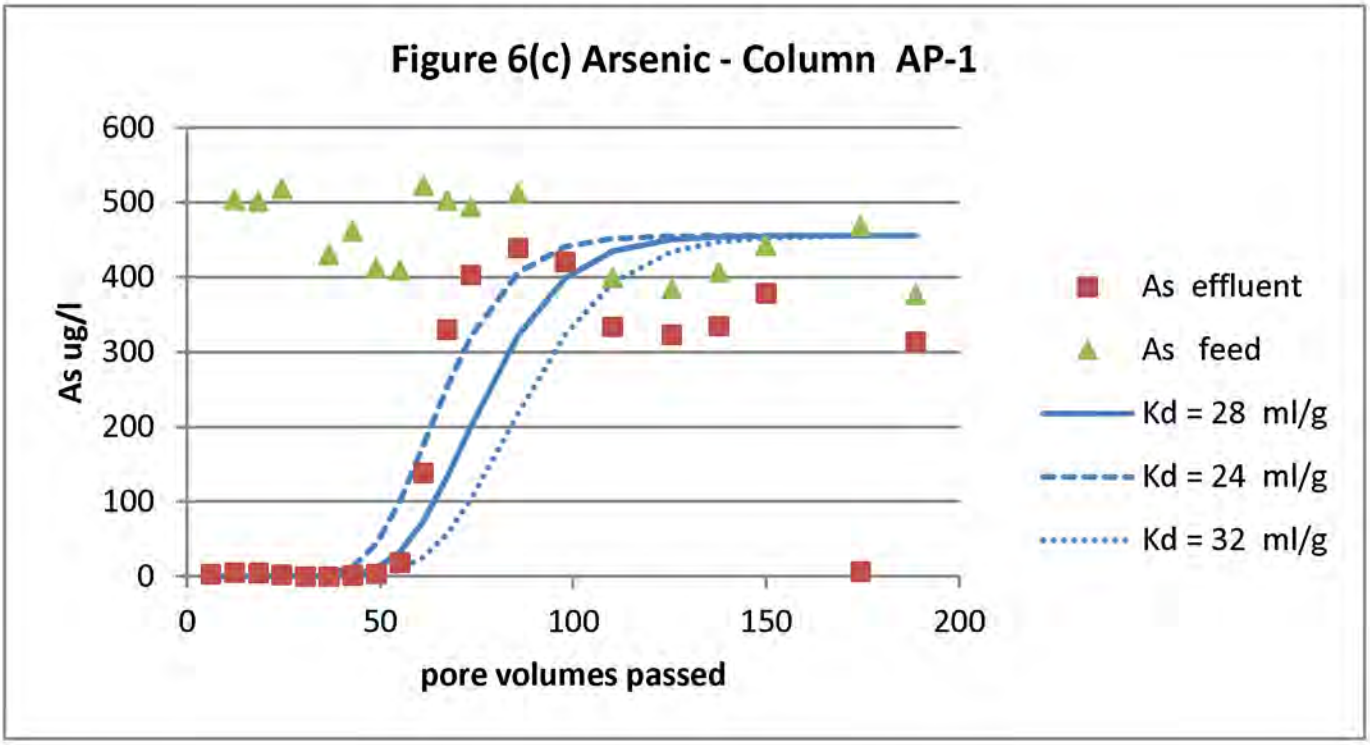


Figure 6(c) Arsenic - Column AP-1
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 28 ml/g
Kd = 24 ml/g
Kd = 32 ml/g

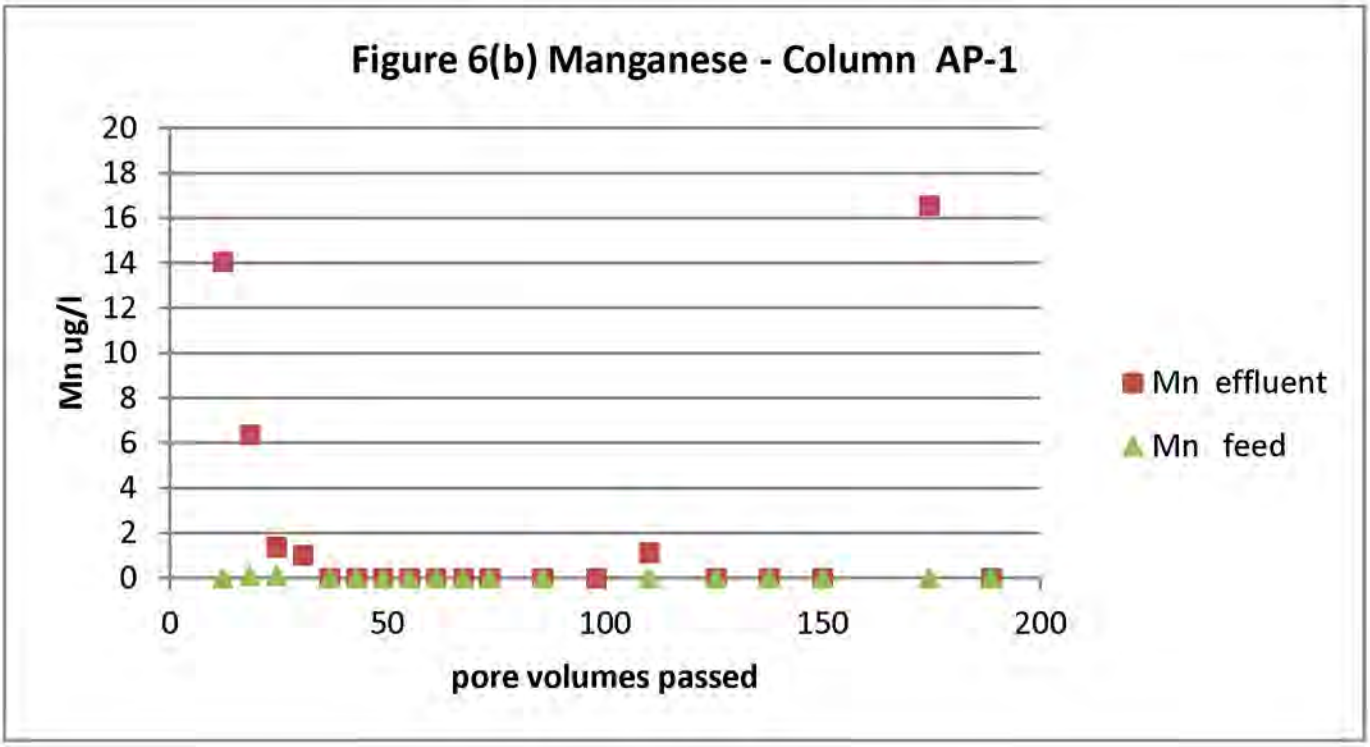


Figure 6(b) Manganese - Column AP-1
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

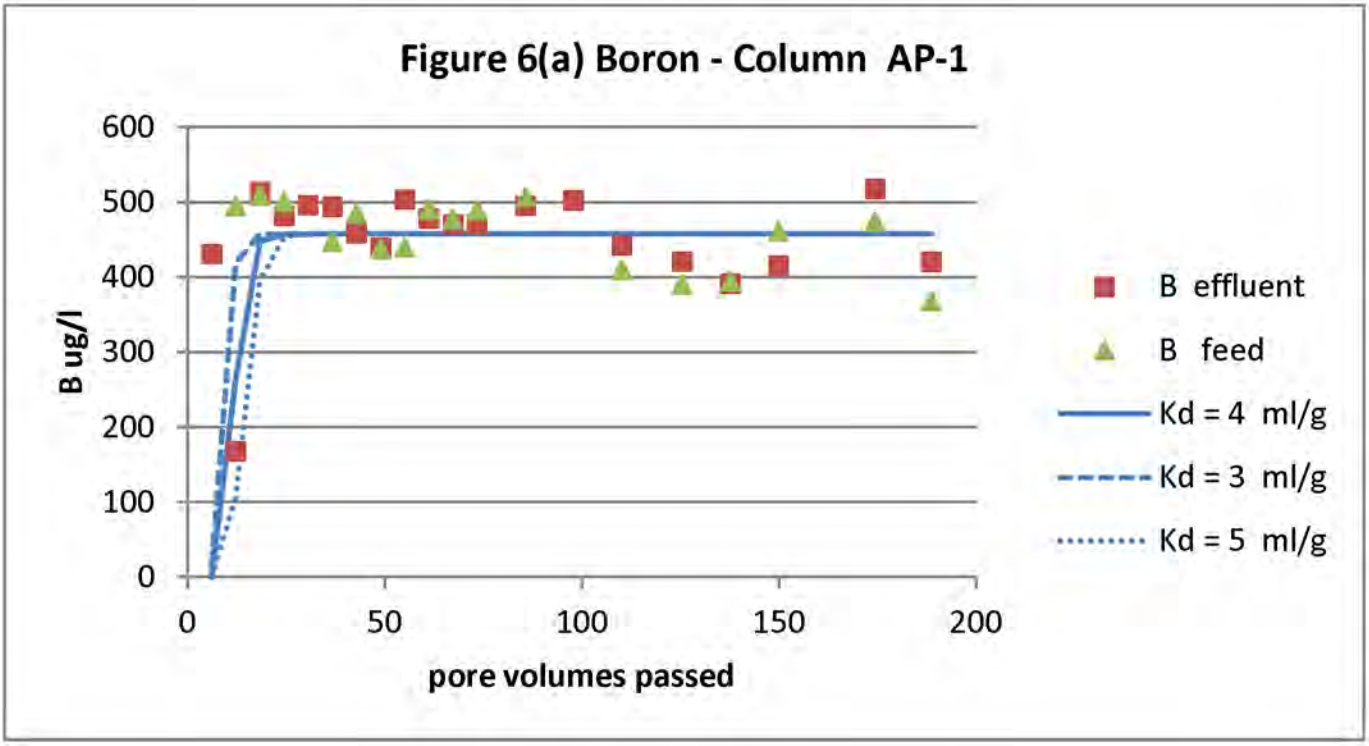


Figure 6(a) Boron - Column AP-1
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 4 ml/g
Kd = 3 ml/g
Kd = 5 ml/g

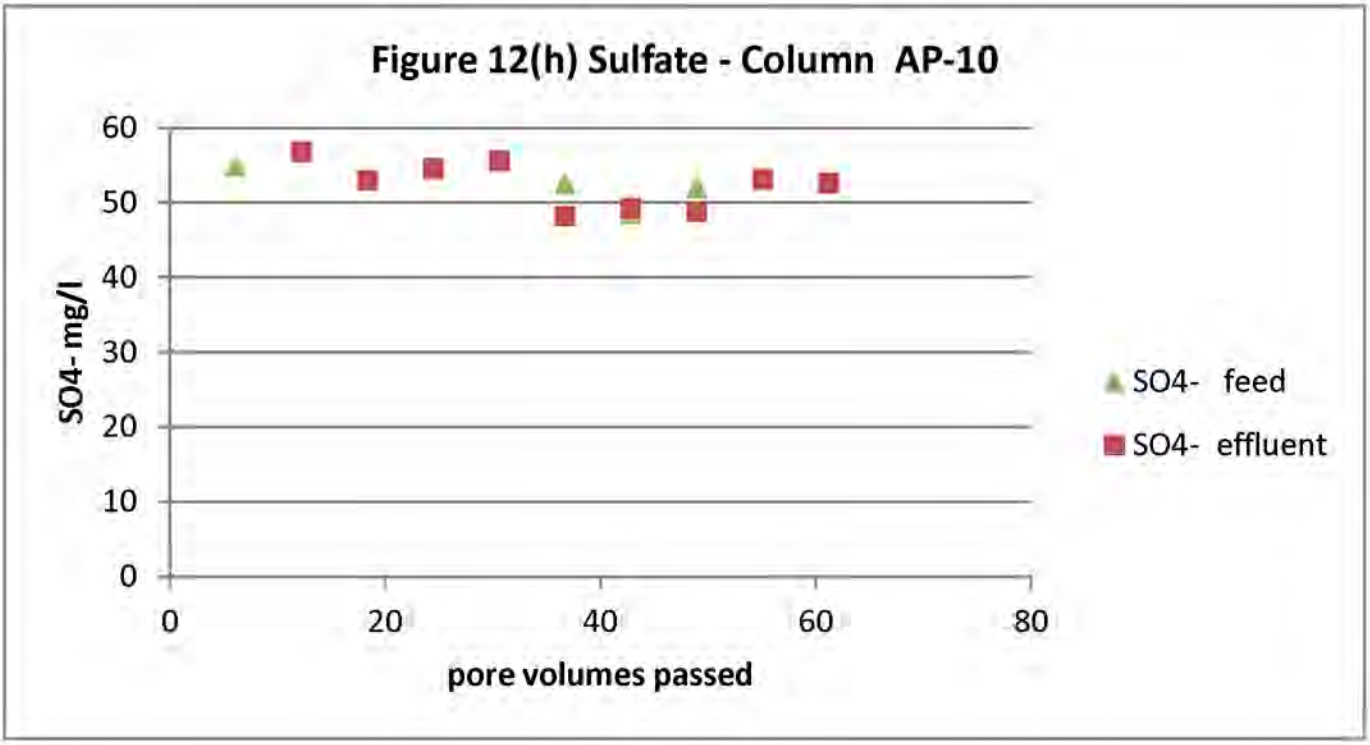


Figure 12(h) Sulfate - Column AP-10
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

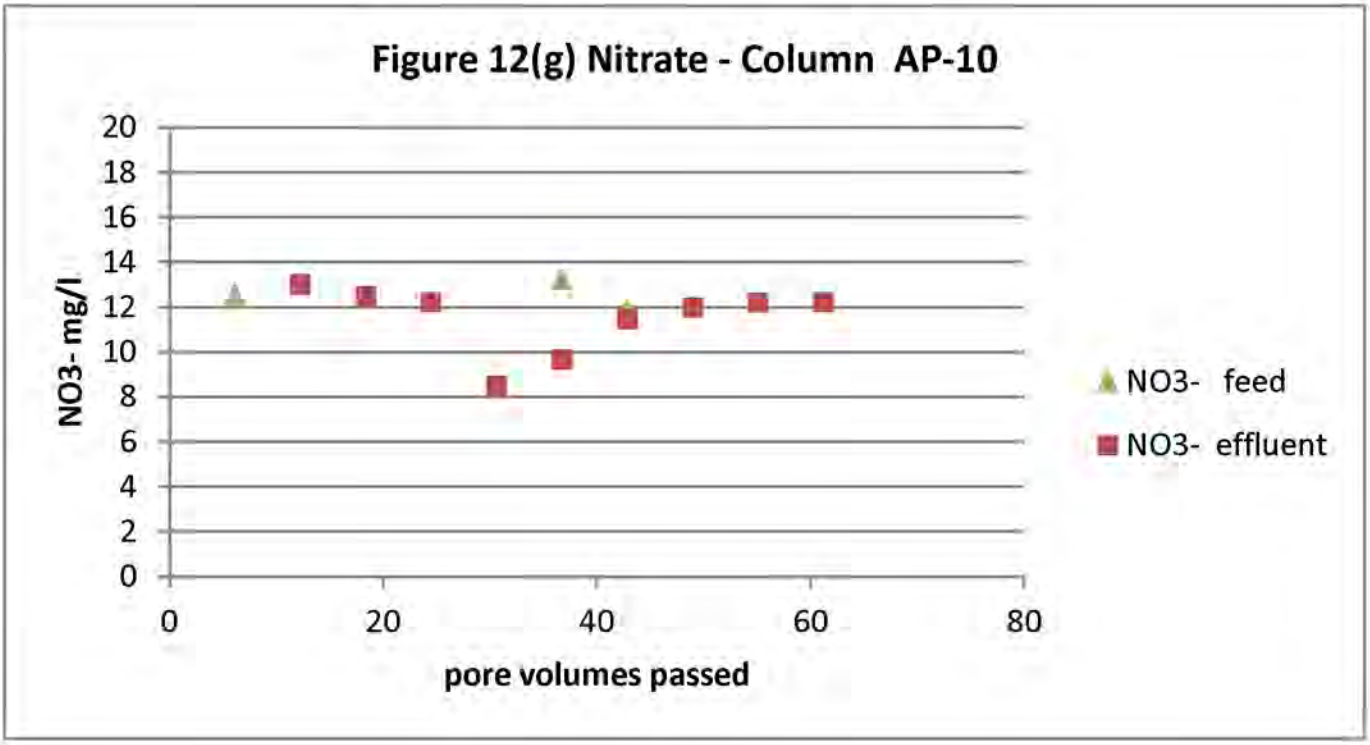


Figure 12(g) Nitrate - Column AP-10
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

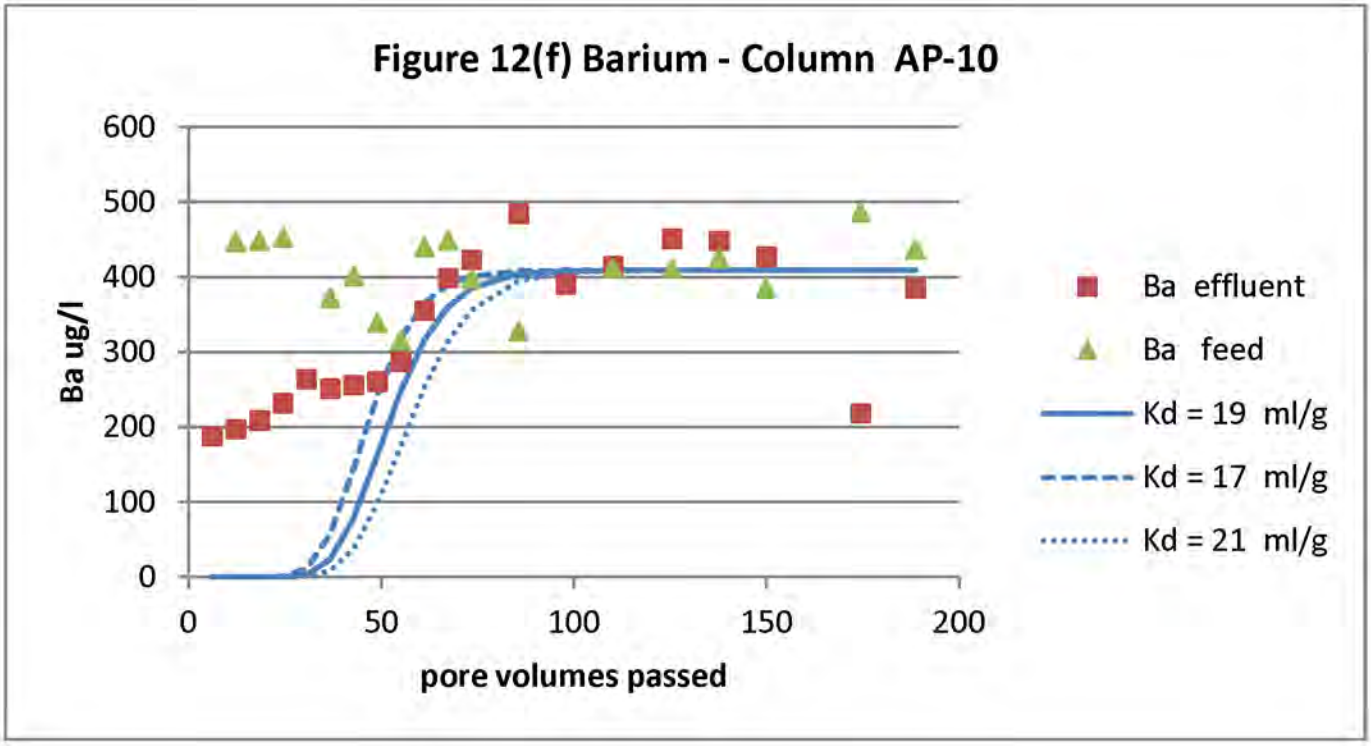


Figure 12(f) Barium - Column AP-10
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 19 ml/g
Kd = 17 ml/g
Kd = 21 ml/g

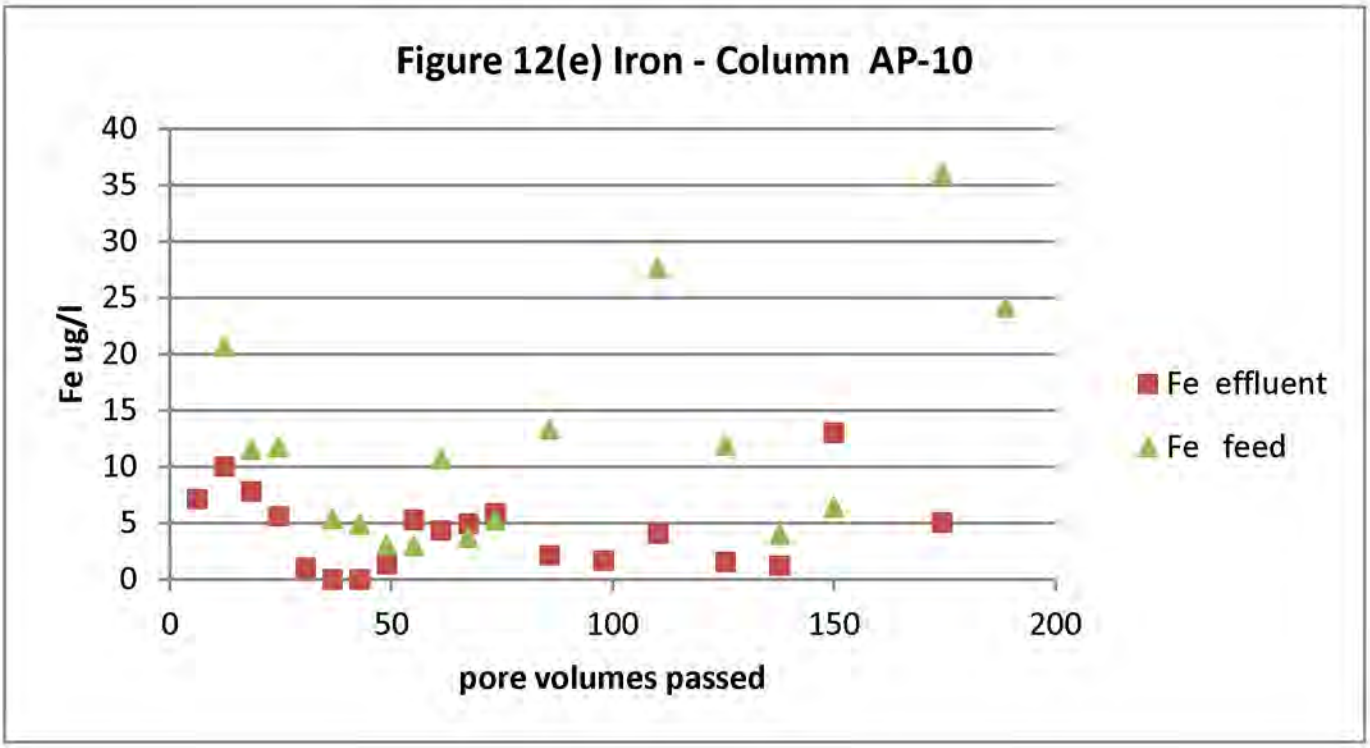


Figure 12(e) Iron - Column AP-10
Fe ug/l
40
35
30
25
20
15
10
5
0
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

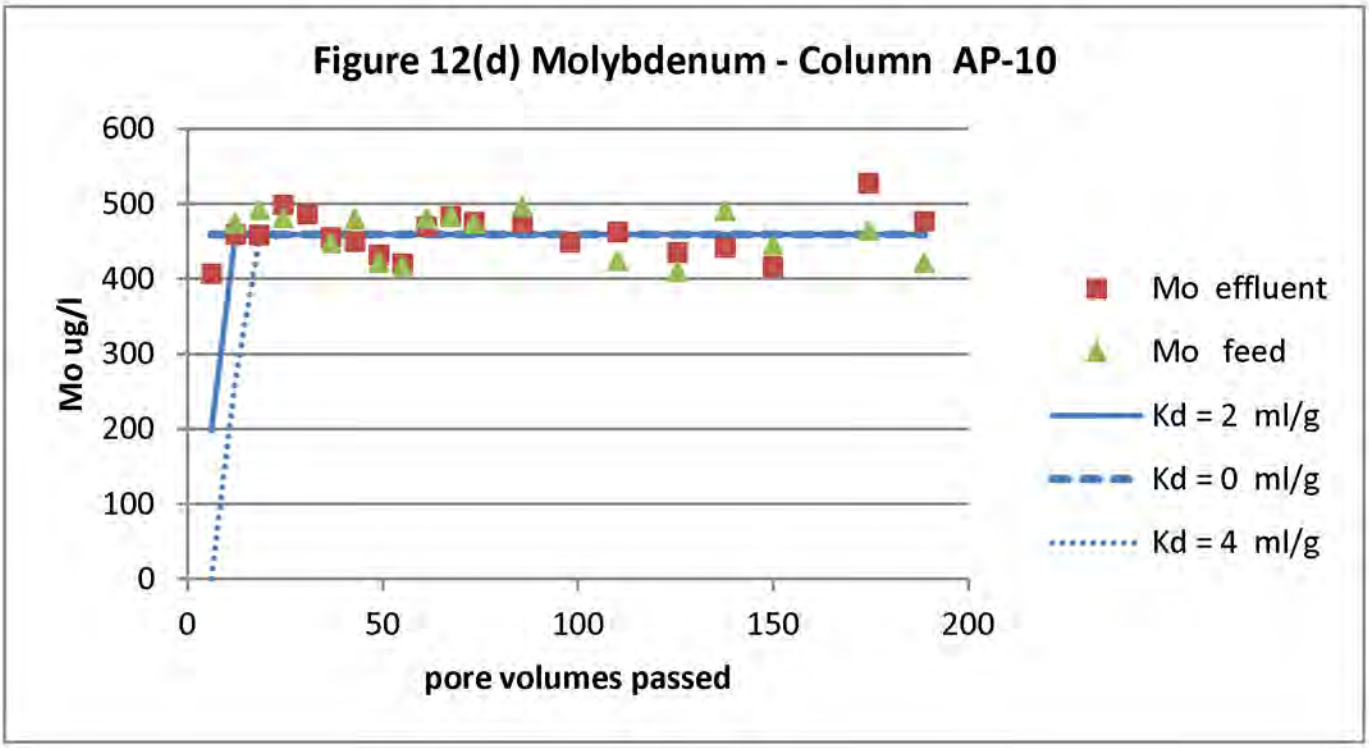


Figure 12(d) Molybdenum - Column AP-10
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 2 ml/g
Kd = 0 ml/g
Kd = 4 ml/g

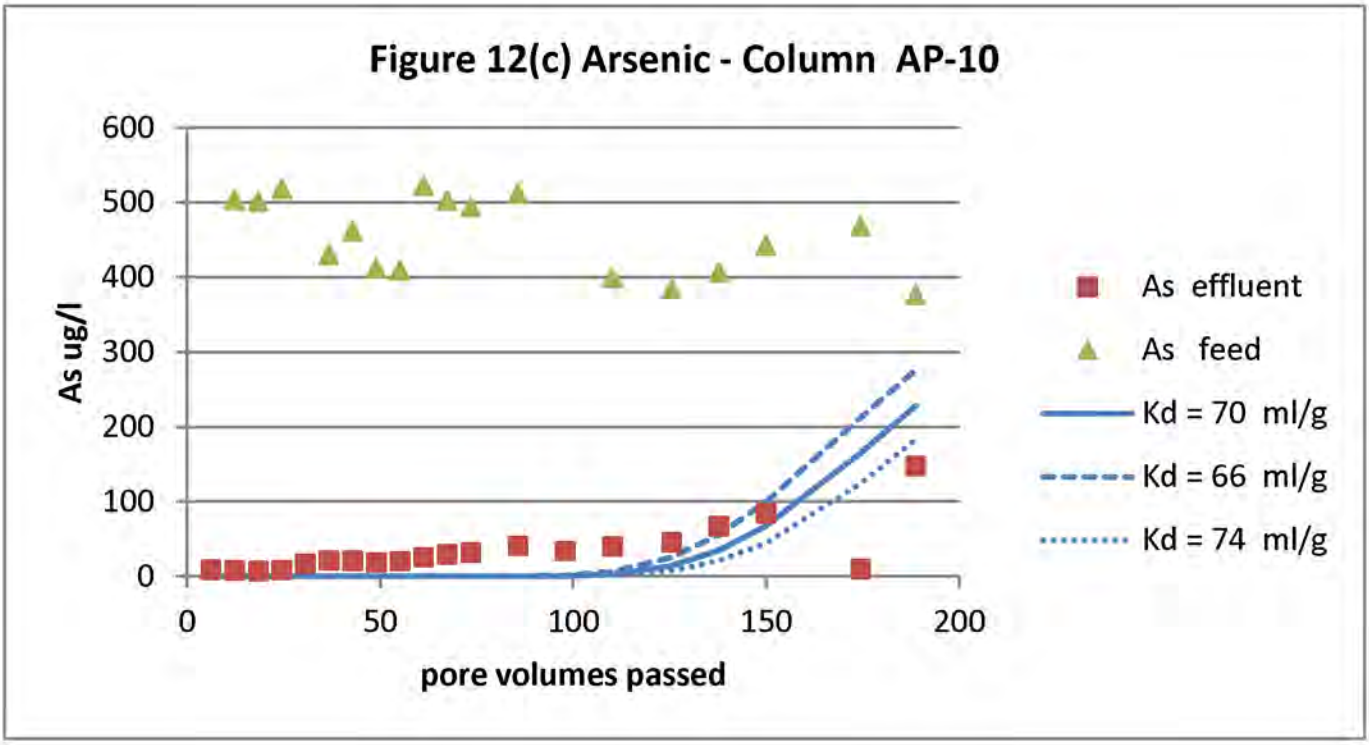


Figure 12(c) Arsenic - Column AP-10
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 70 ml/g
Kd = 66 ml/g
Kd = 74 ml/g

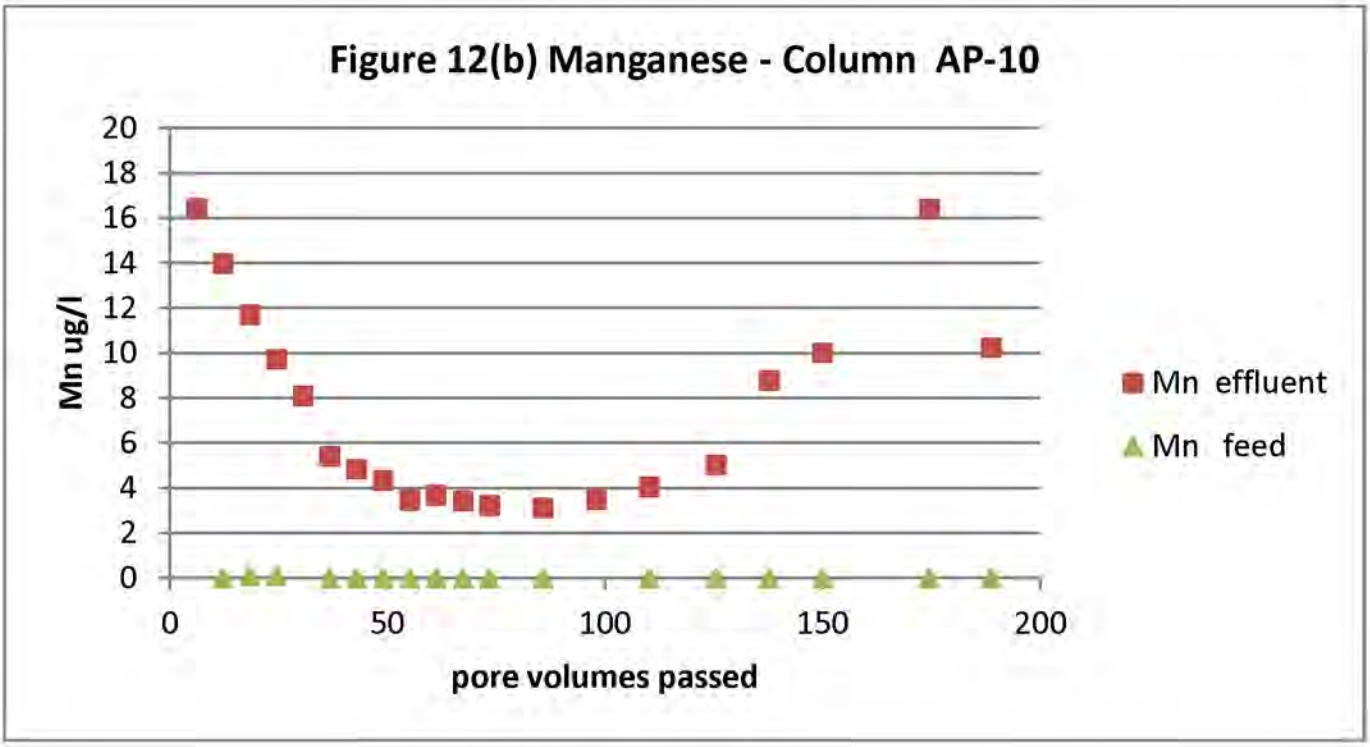


Figure 12(b) Manganese - Column AP-10
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

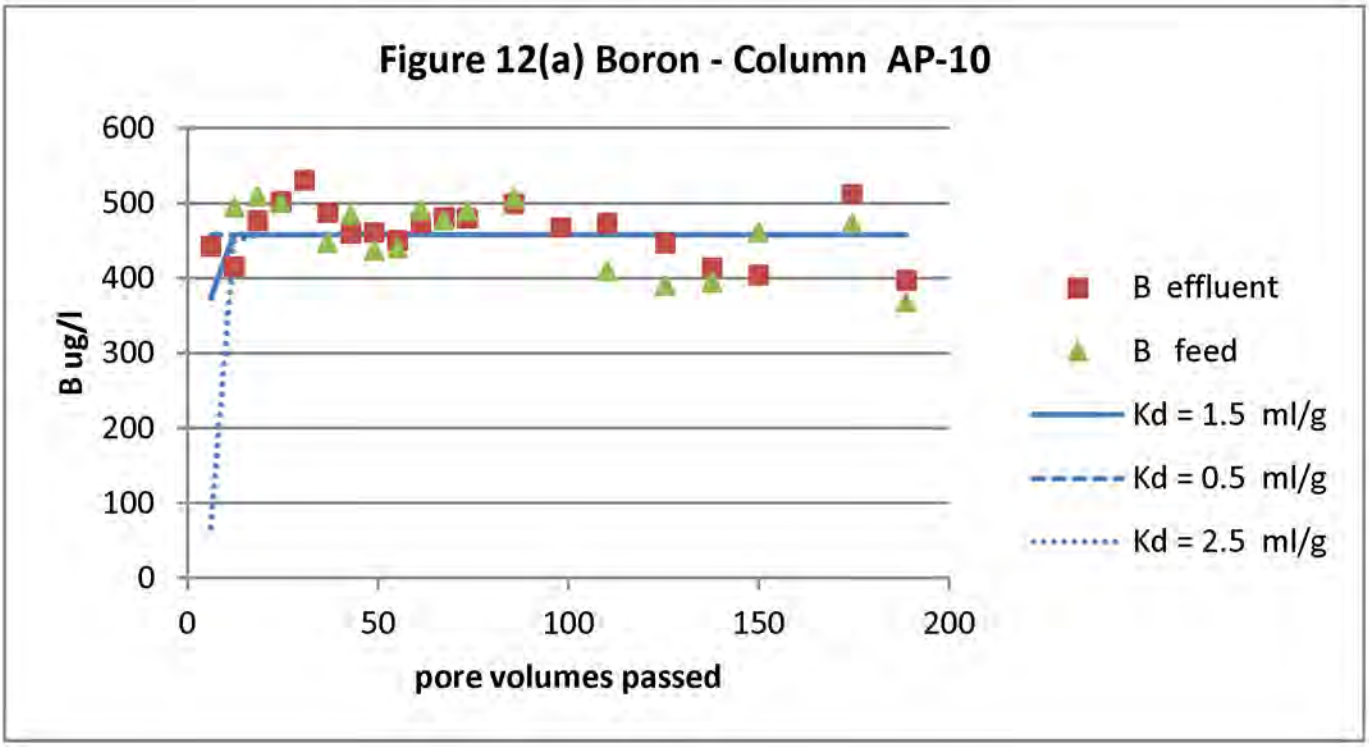


Figure 12(a) Boron - Column AP-10
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 1.5 ml/g
Kd = 0.5 ml/g
Kd = 2.5 ml/g

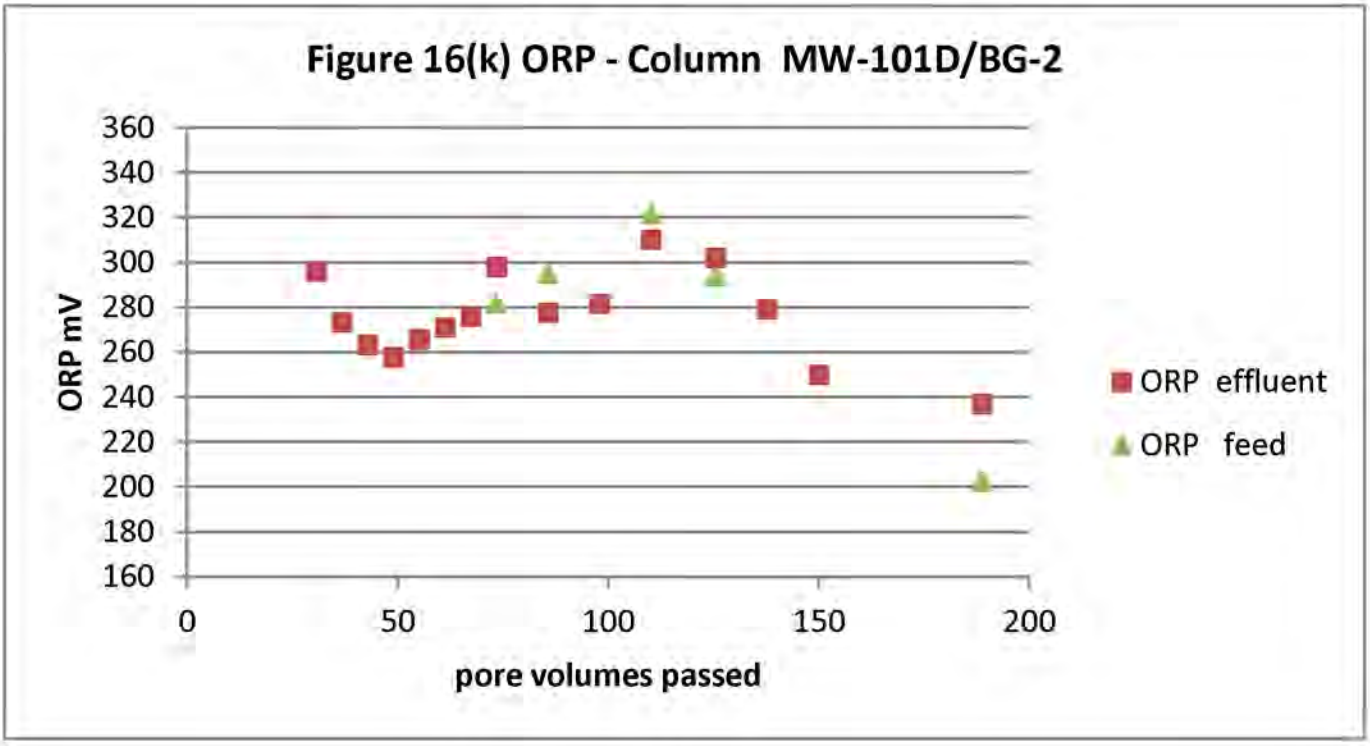


Figure 16(k) ORP - Column MW-101D/BG-2
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

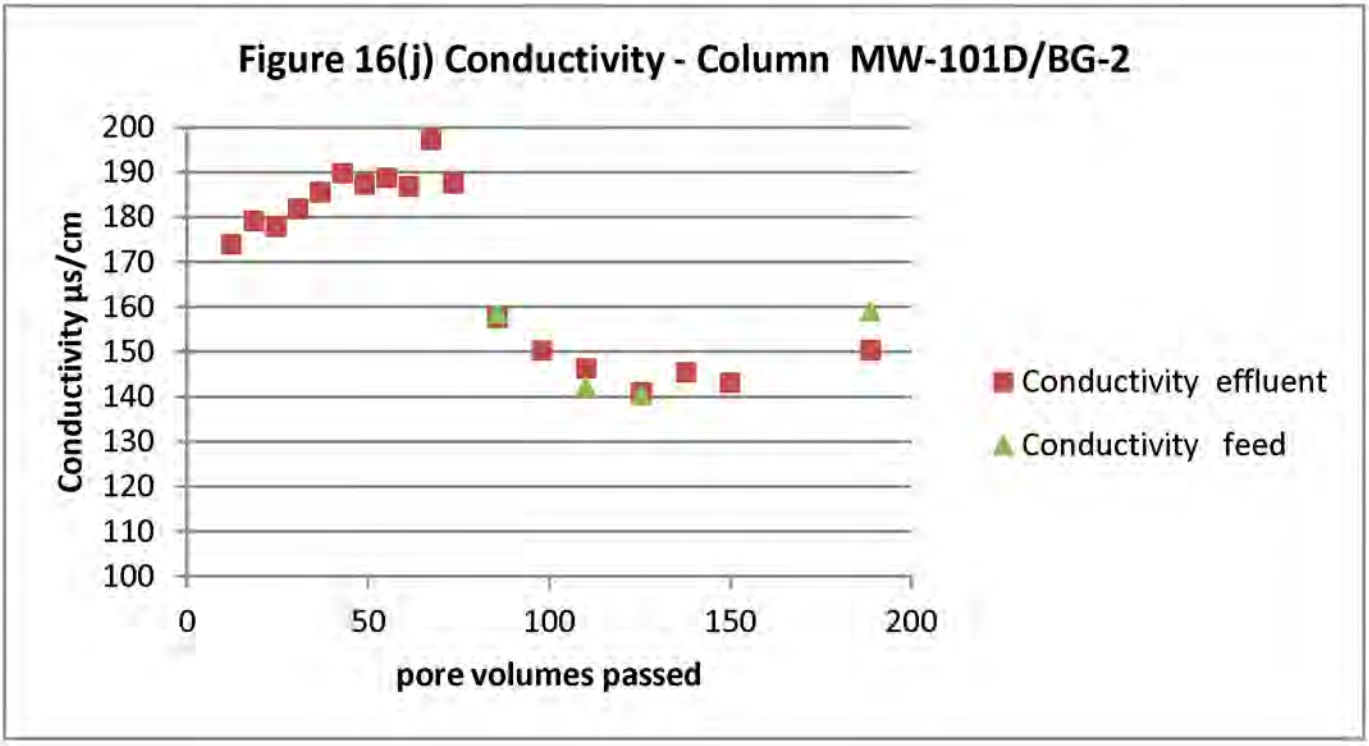


Figure 16(j) Conductivity - Column MW-101D/BG-2
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

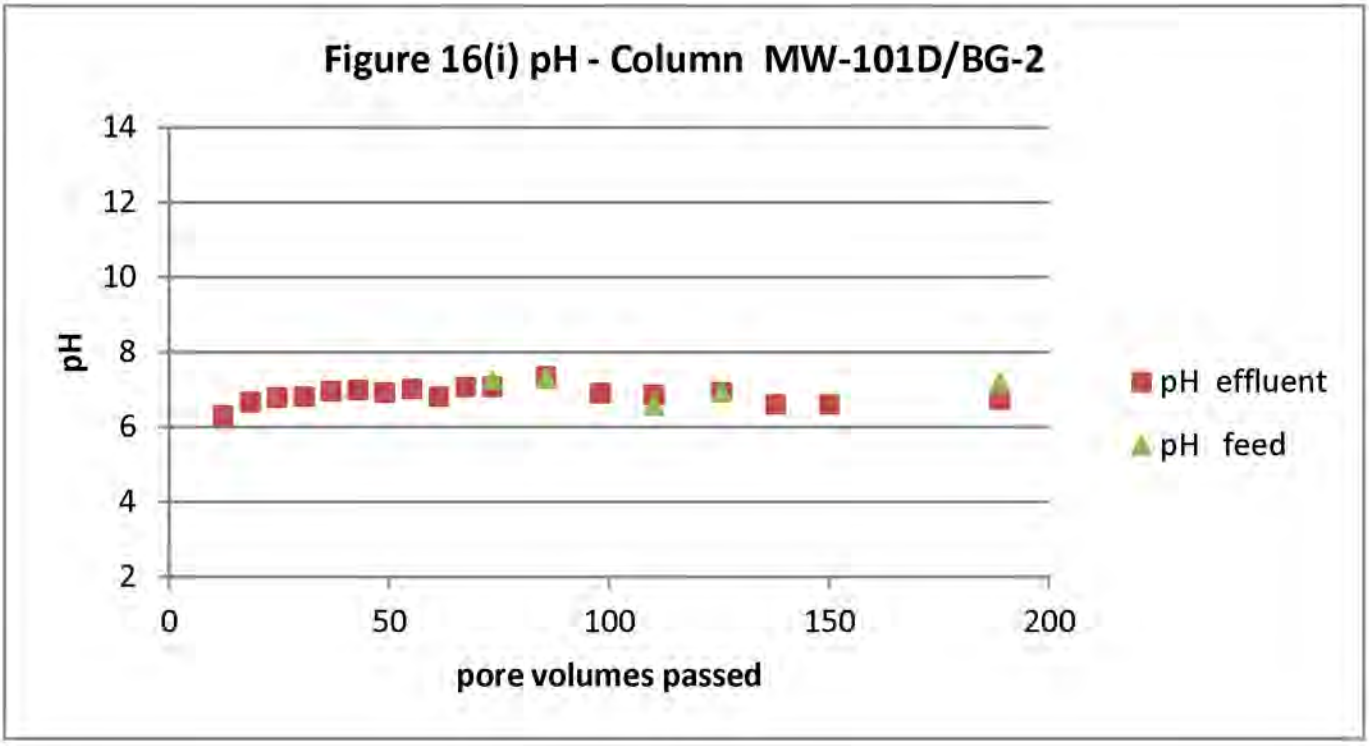


Figure 16(i) pH - Column MW-101D/BG-2
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

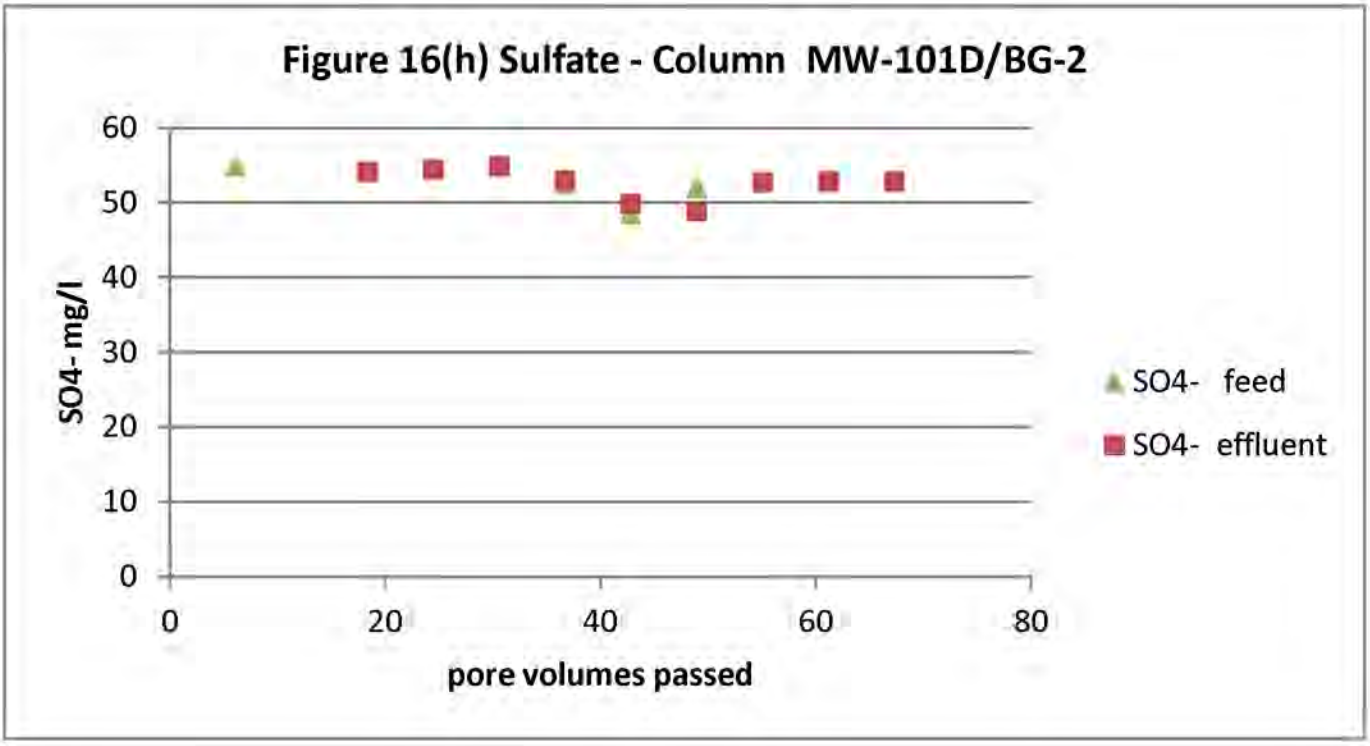


Figure 16(h) Sulfate - Column MW-101D/BG-2
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

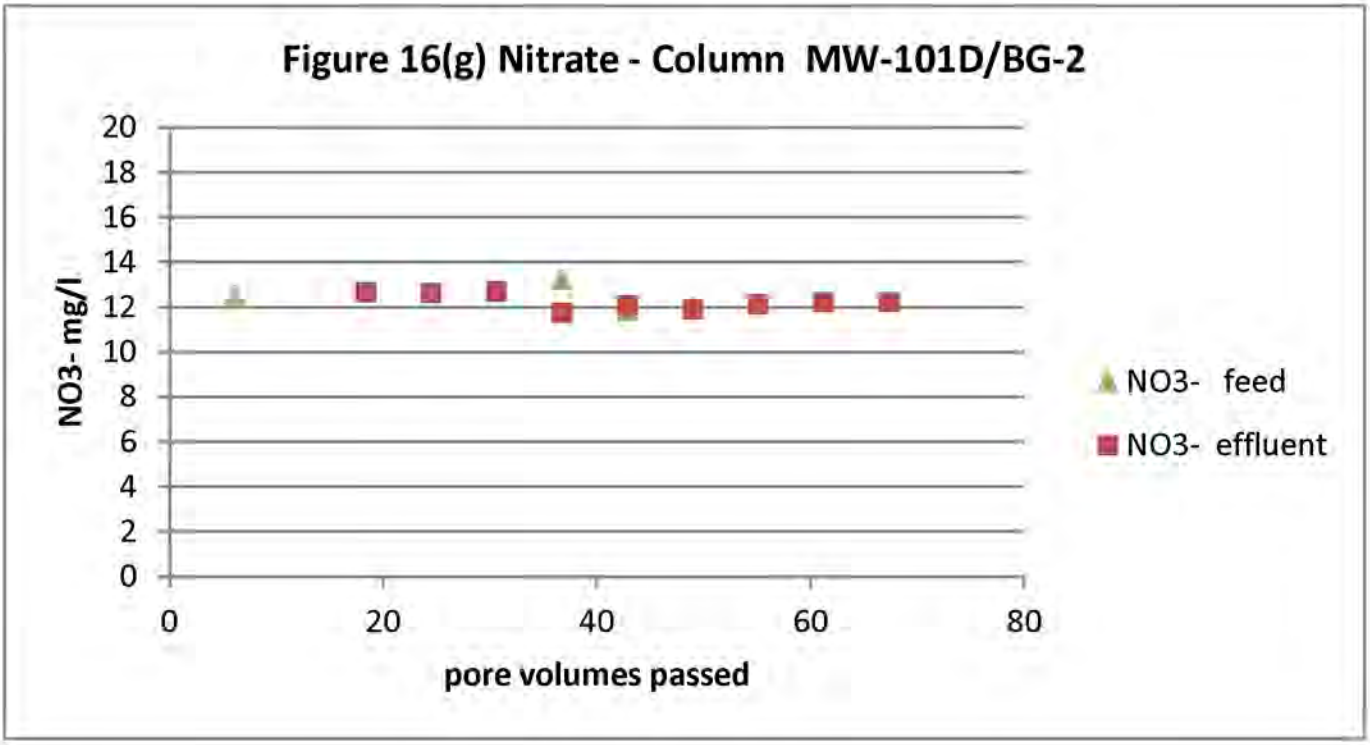


Figure 16(g) Nitrate - Column MW-101D/BG-2
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

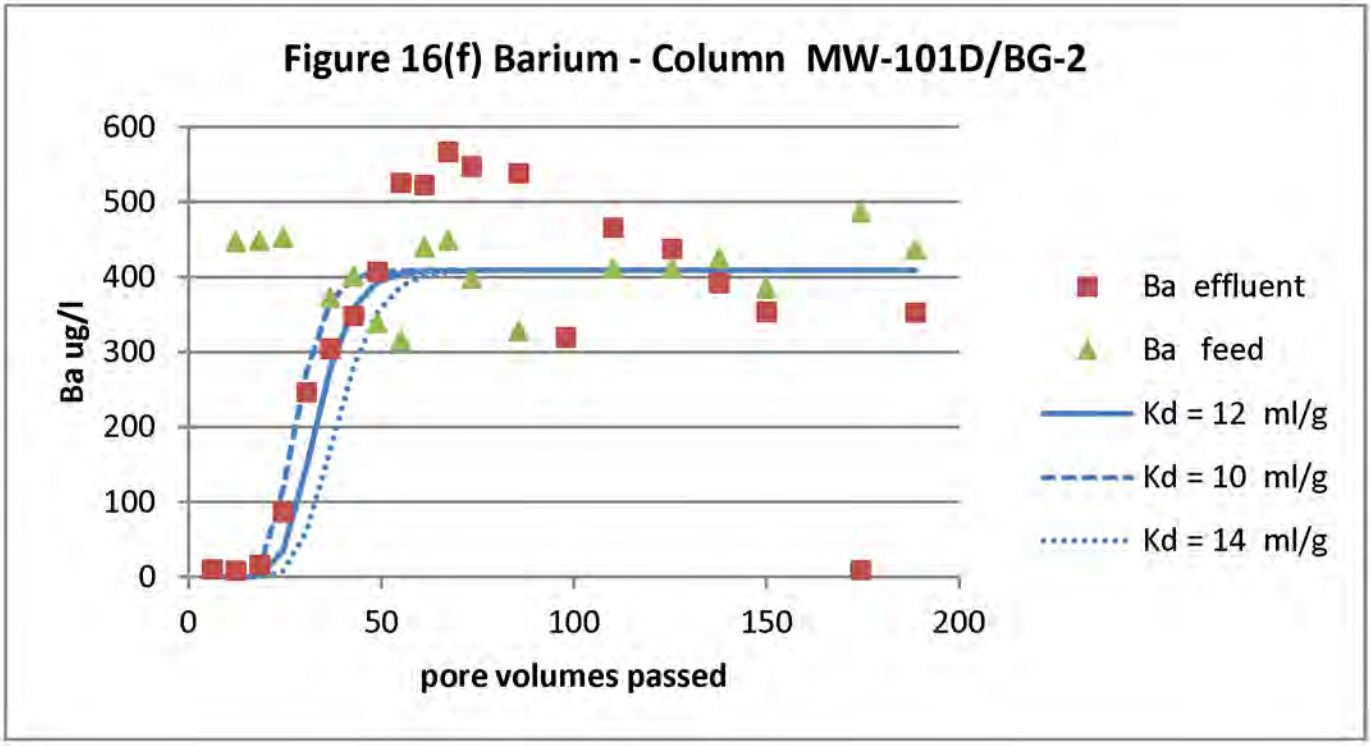


Figure 16(f) Barium - Column MW-101D/BG-2
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 12 ml/g
Kd = 10 ml/g
Kd = 14 ml/g

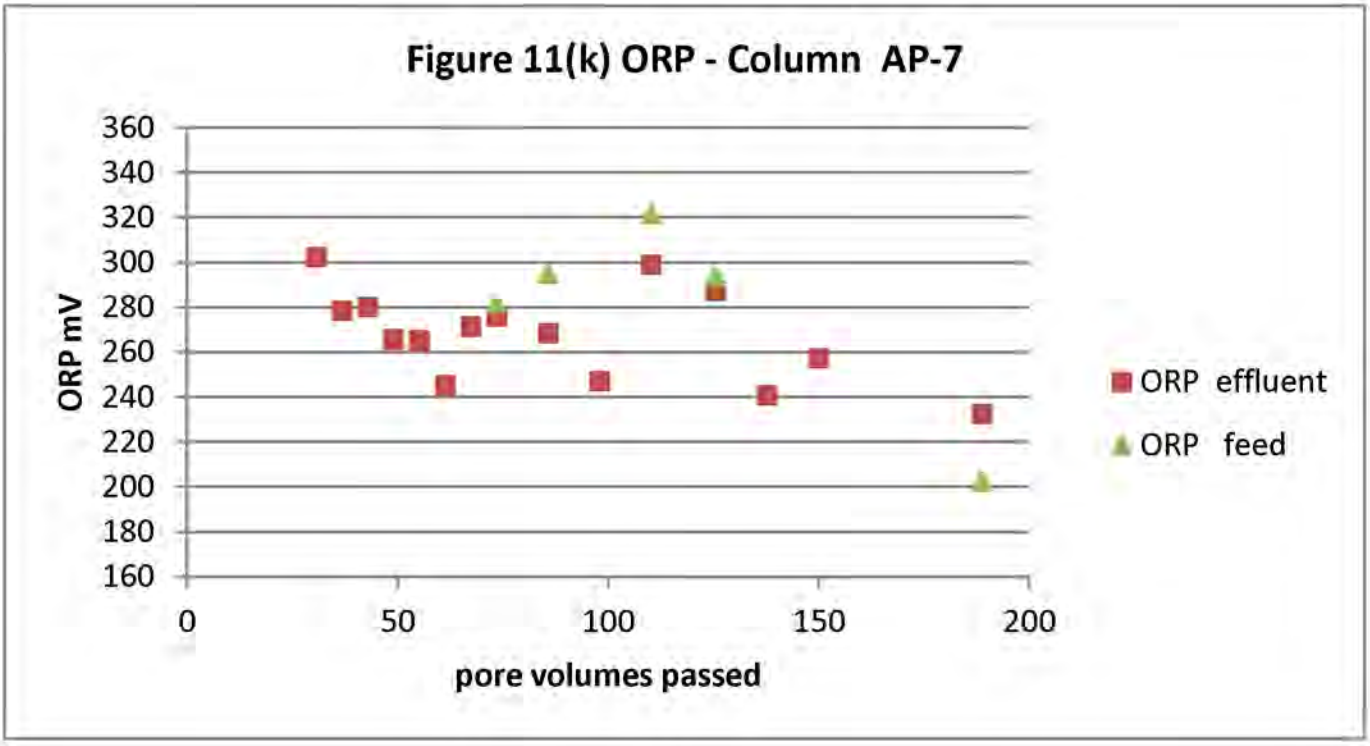


Figure 11(k) ORP - Column AP-7
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

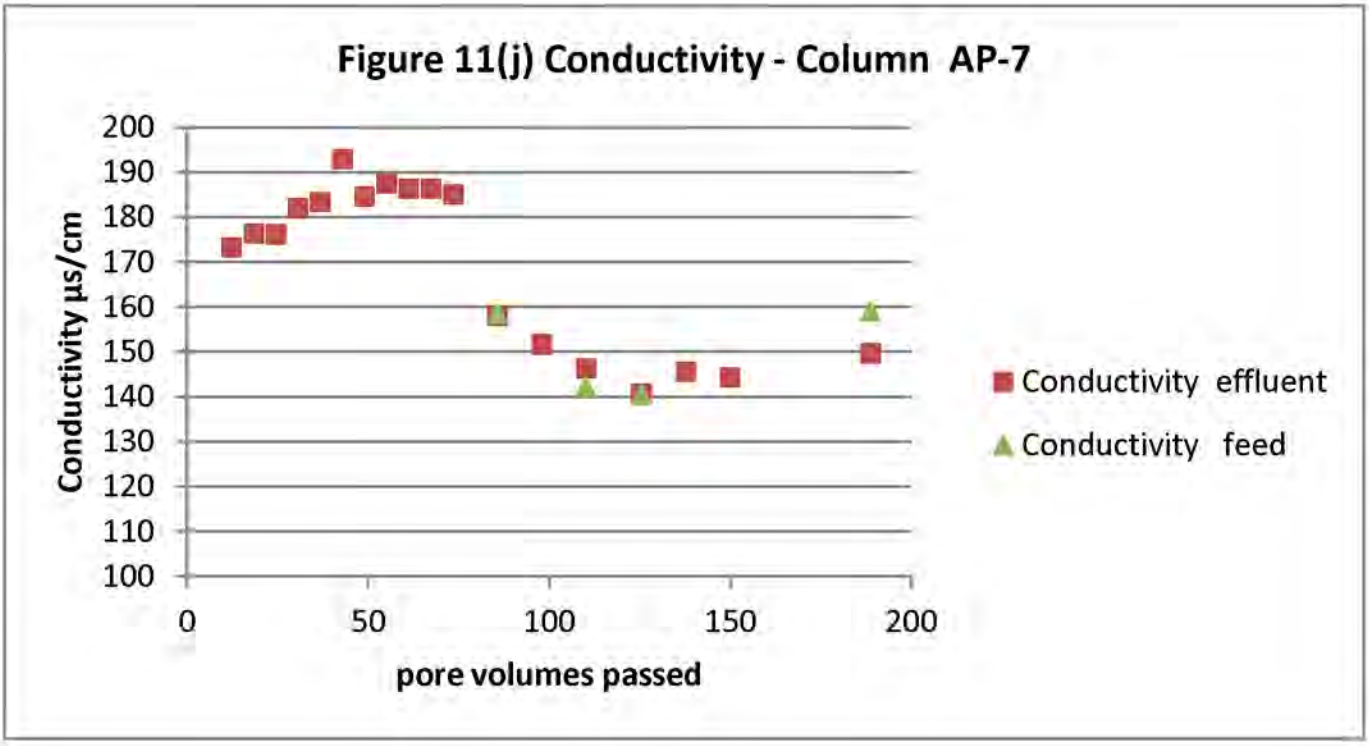


Figure 11(j) Conductivity - Column AP-7
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

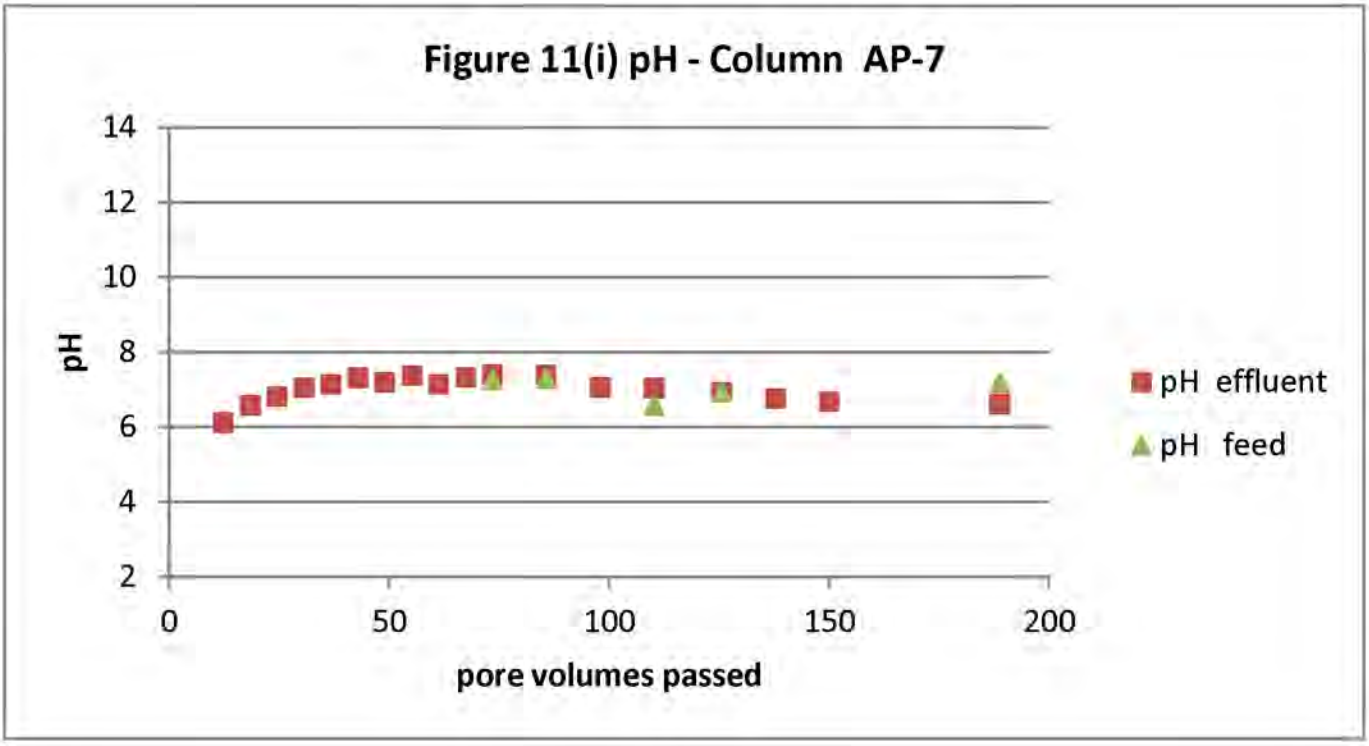


Figure 11(i) pH - Column AP-7
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

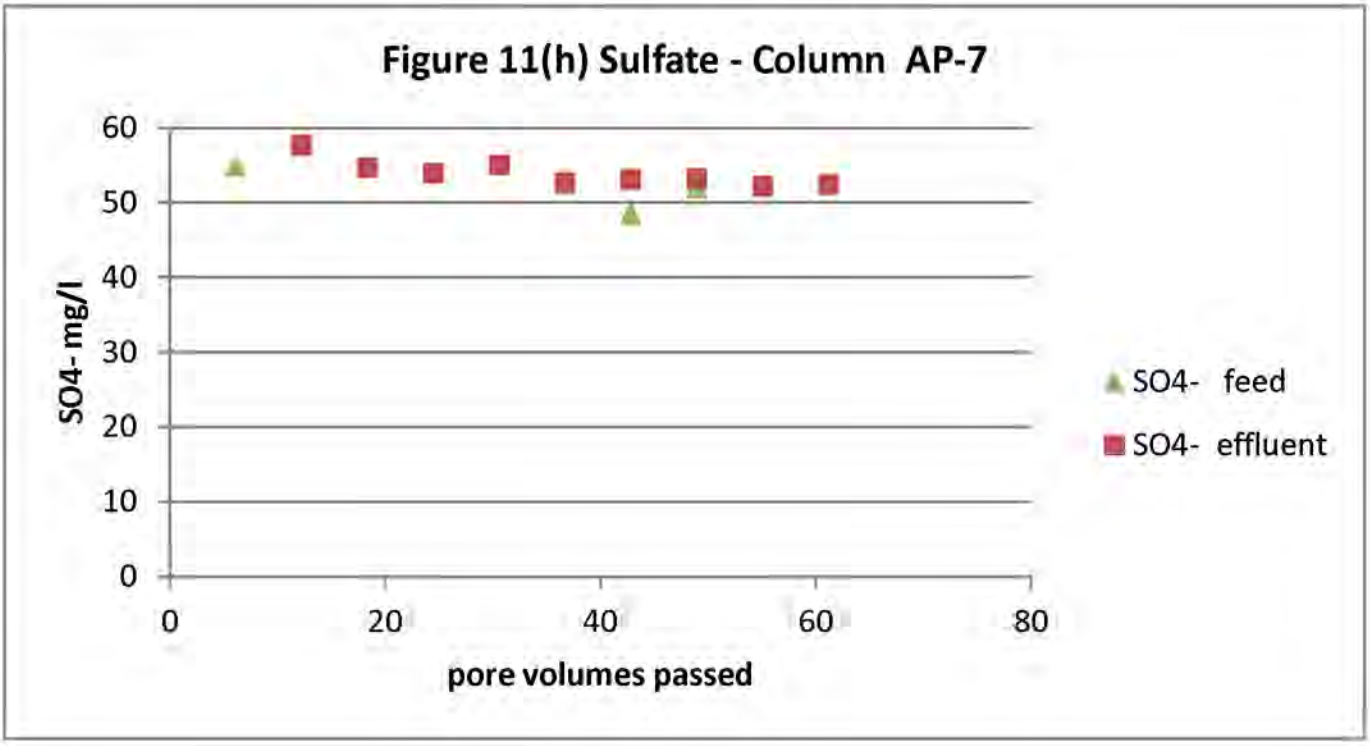


Figure 11(h) Sulfate - Column AP-7
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

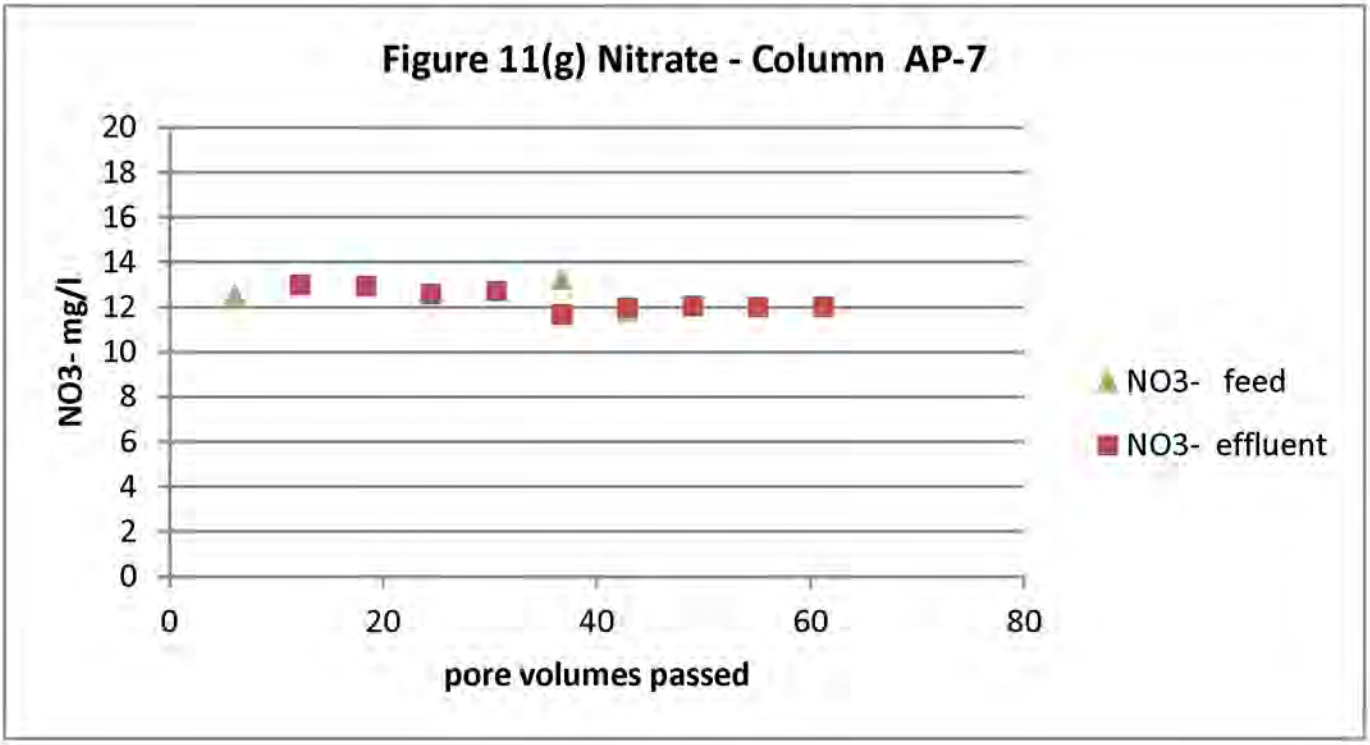


Figure 11(g) Nitrate - Column AP-7
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

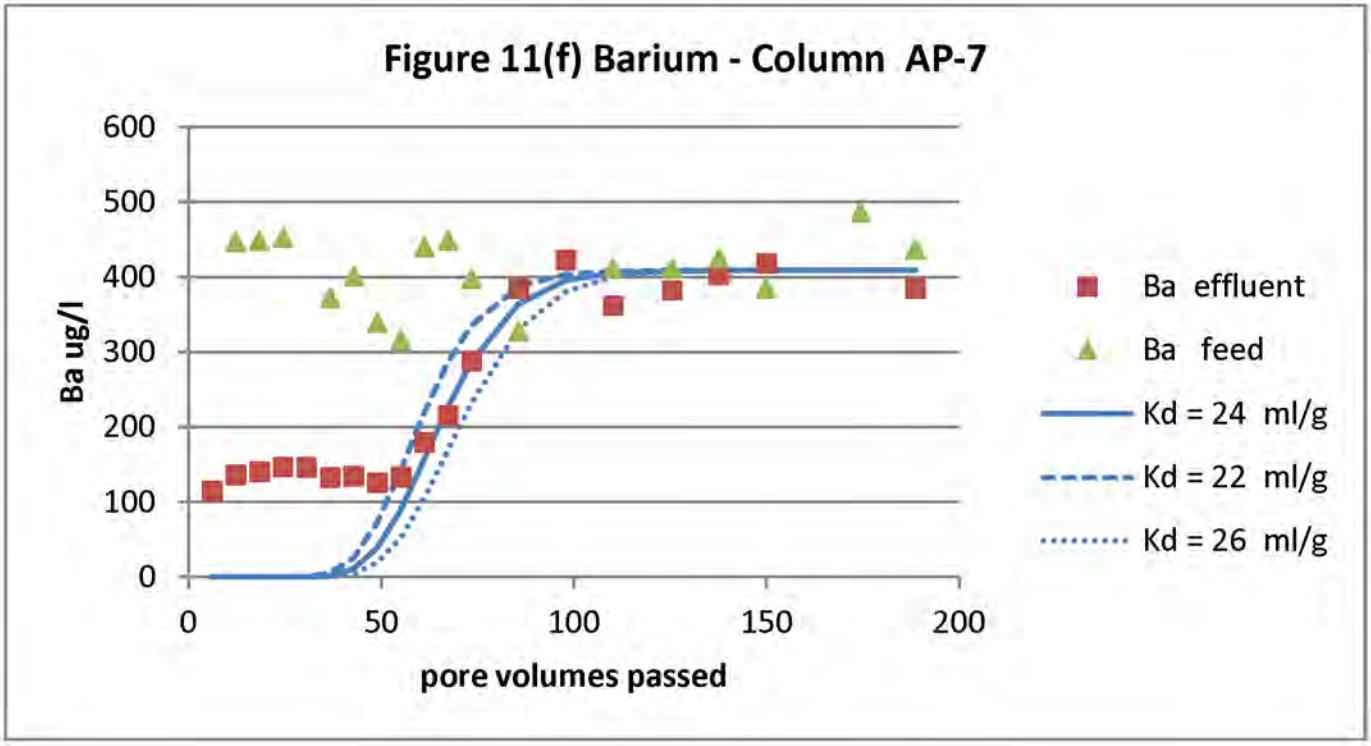


Figure 11(f) Barium - Column AP-7
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 24 ml/g
Kd = 22 ml/g
Kd = 26 ml/g

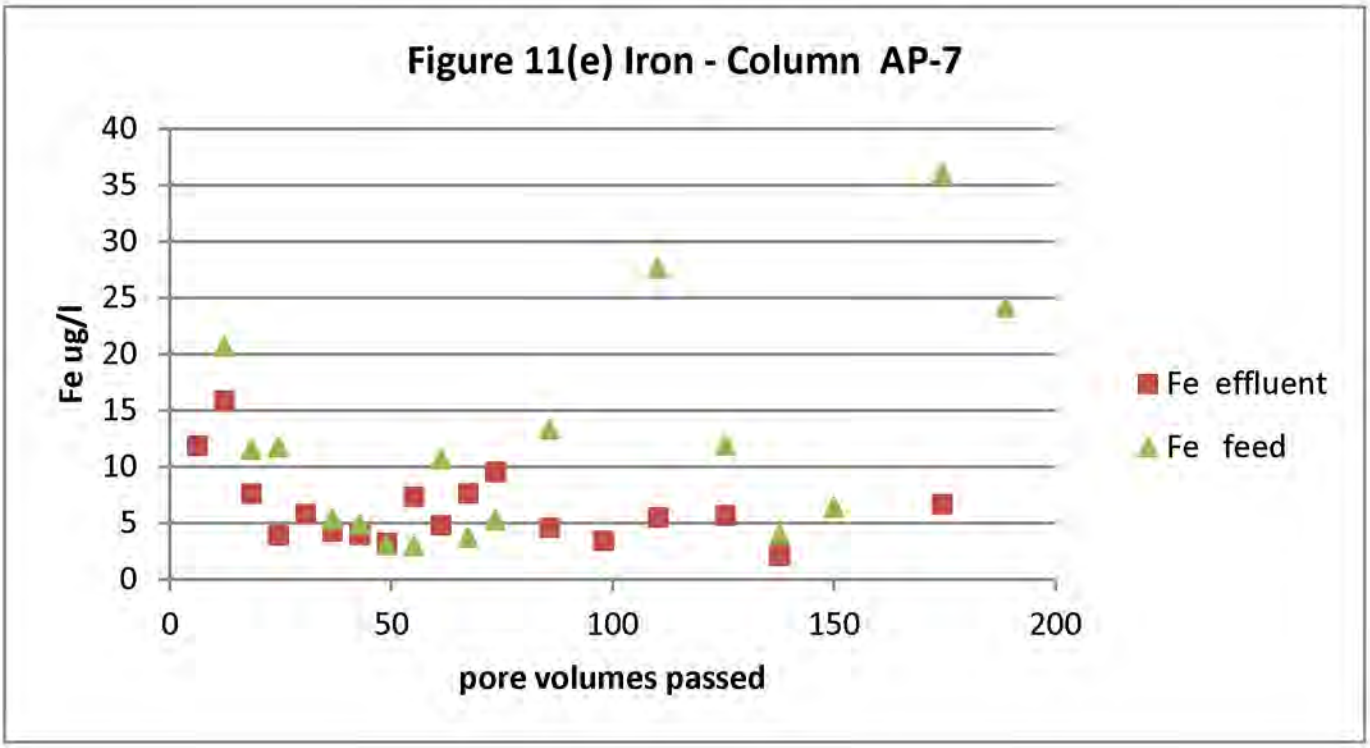


Figure 11(e) Iron - Column AP-7
Fe ug/l
40
35
30
25
20
15
10
5
0
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

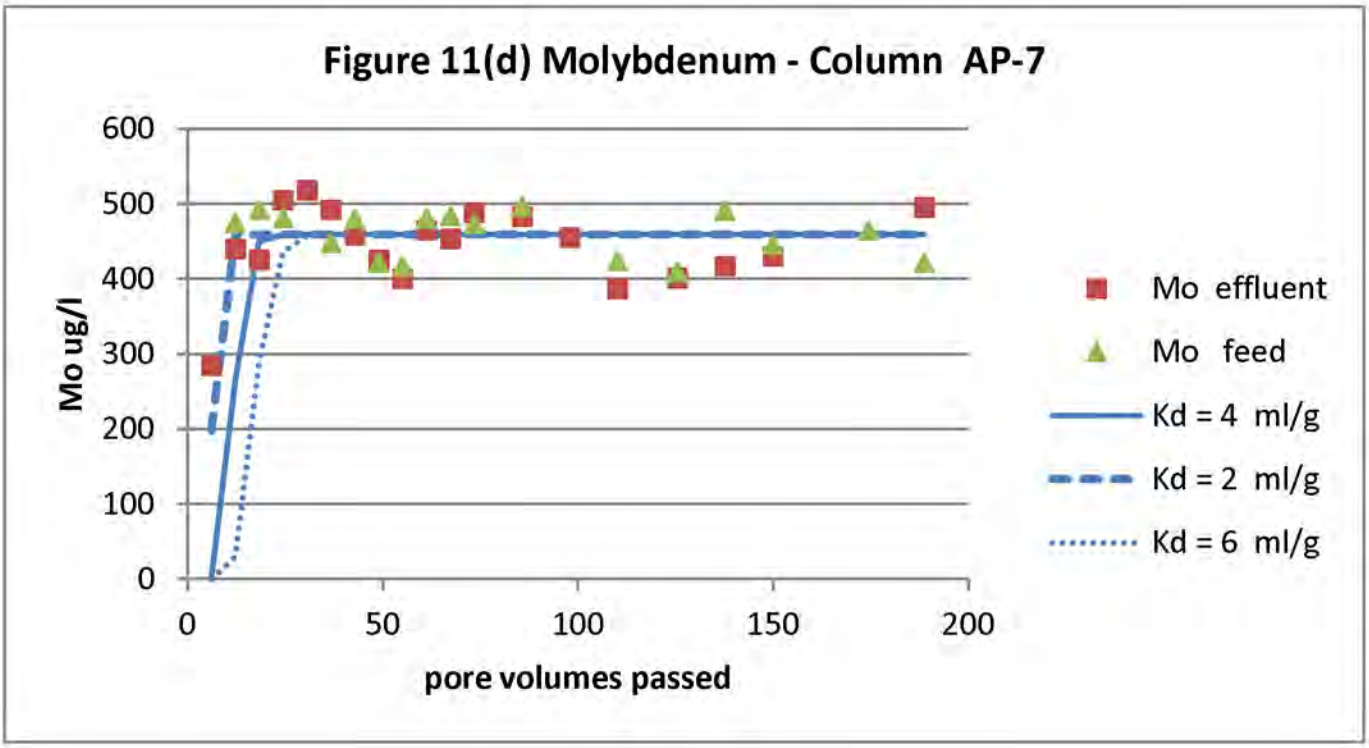


Figure 11(d) Molybdenum - Column AP-7
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 4 ml/g
Kd = 2 ml/g
Kd = 6 ml/g

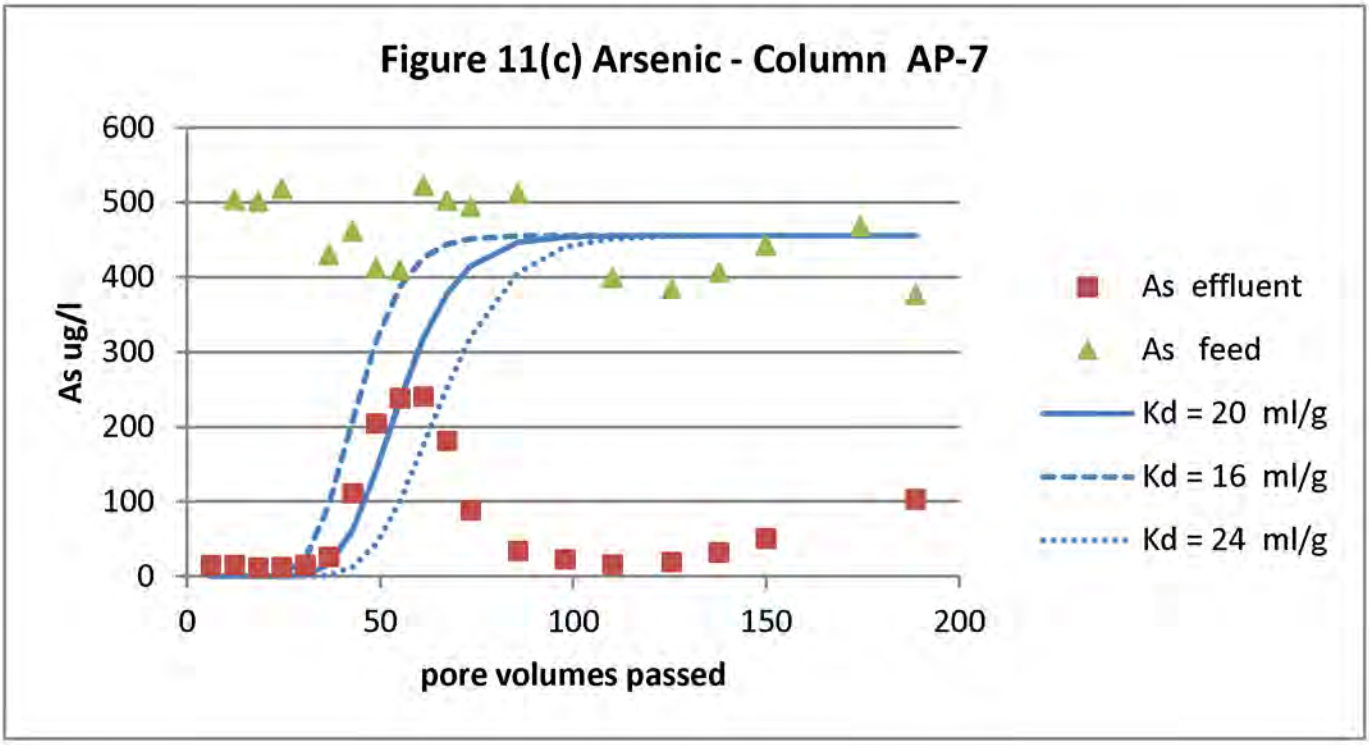


Figure 11(c) Arsenic - Column AP-7
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 20 ml/g
Kd = 16 ml/g
Kd = 24 ml/g

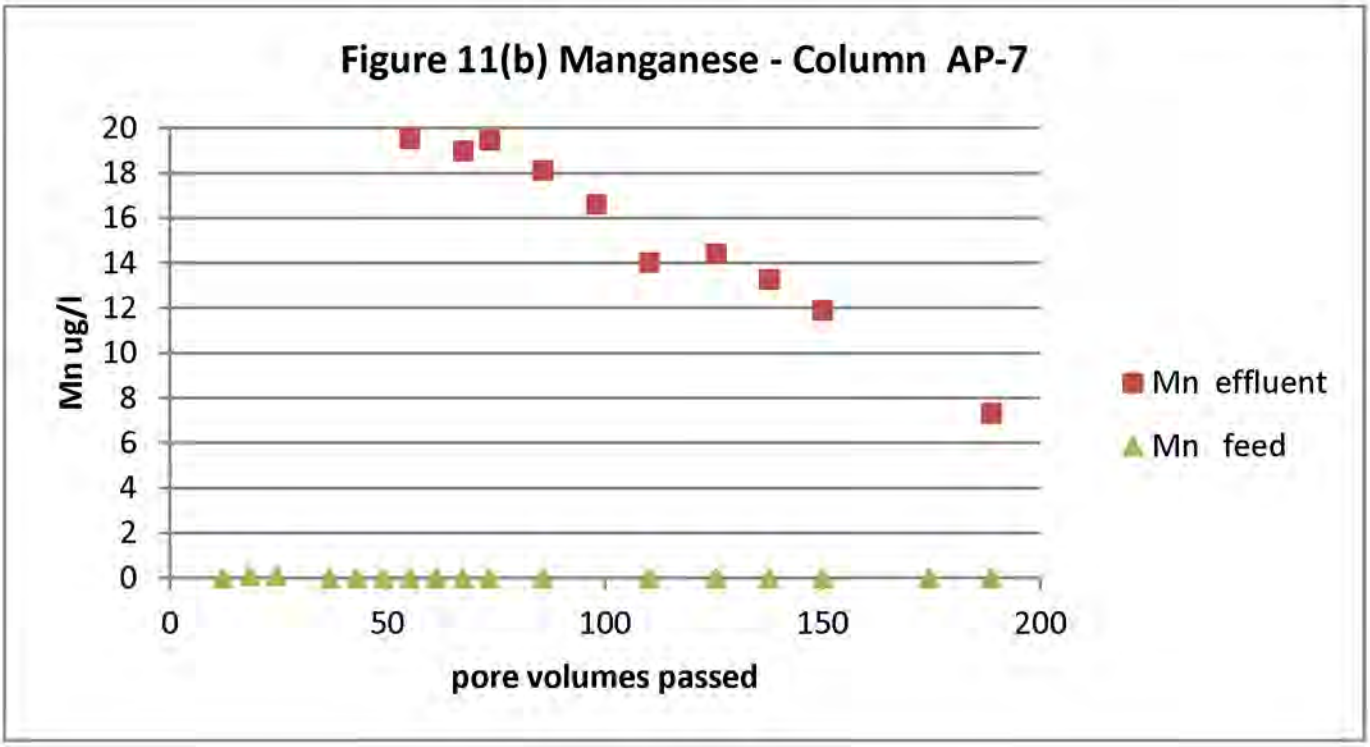


Figure 11(b) Manganese - Column AP-7
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

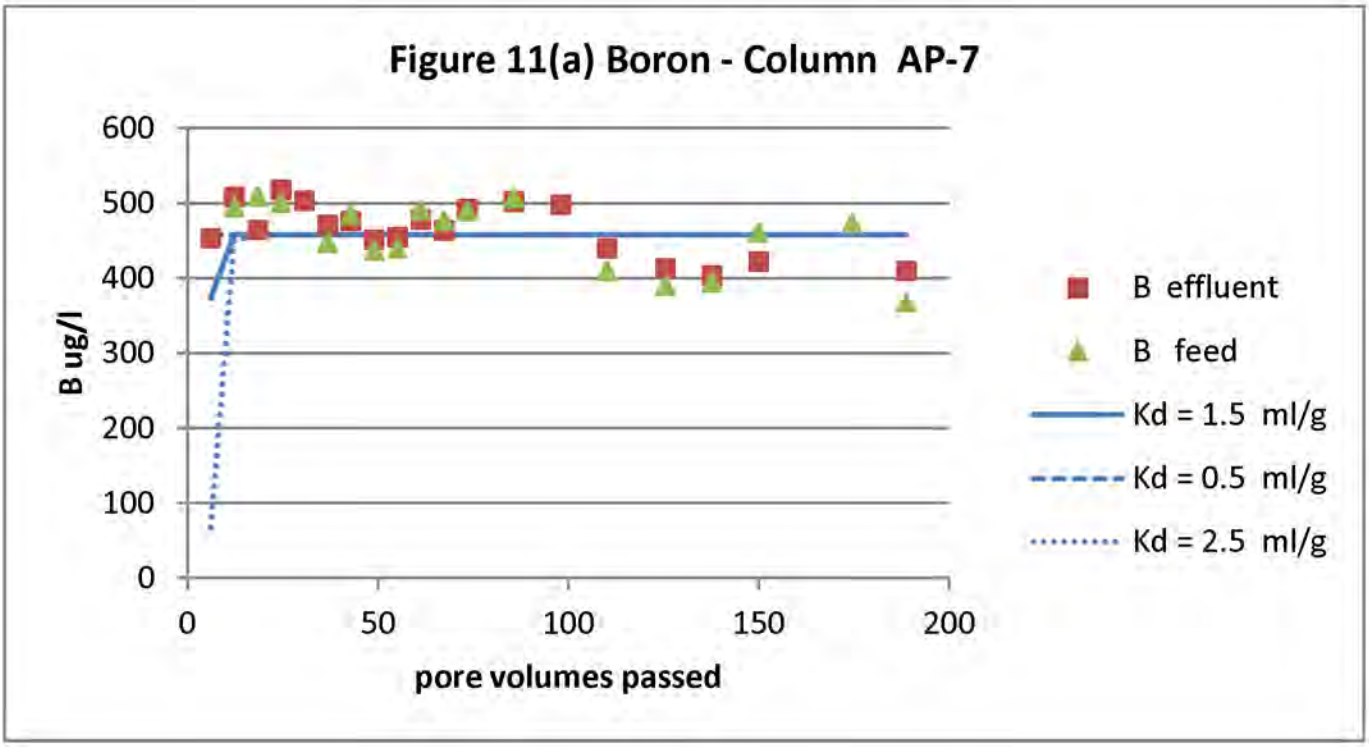


Figure 11(a) Boron - Column AP-7
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 1.5 ml/g
Kd = 0.5 ml/g
Kd = 2.5 ml/g

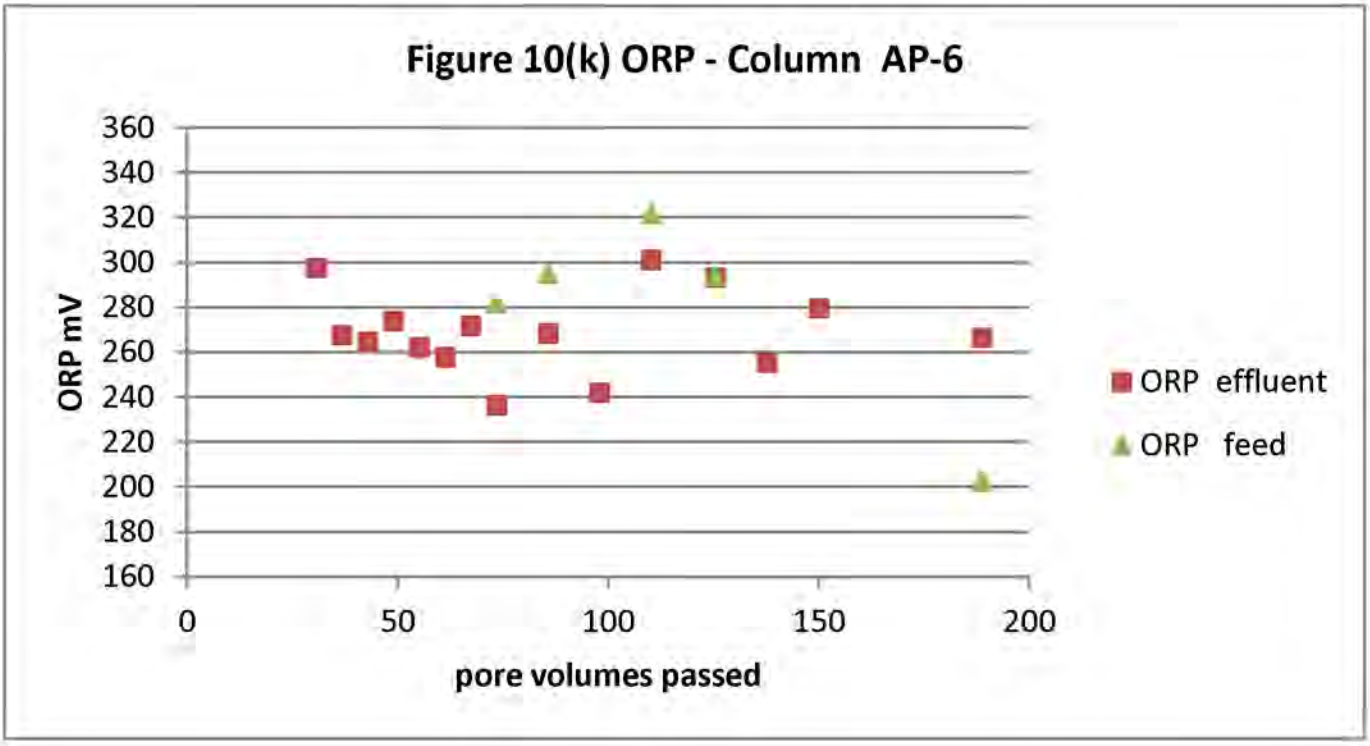


Figure 10(k) ORP - Column AP-6
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

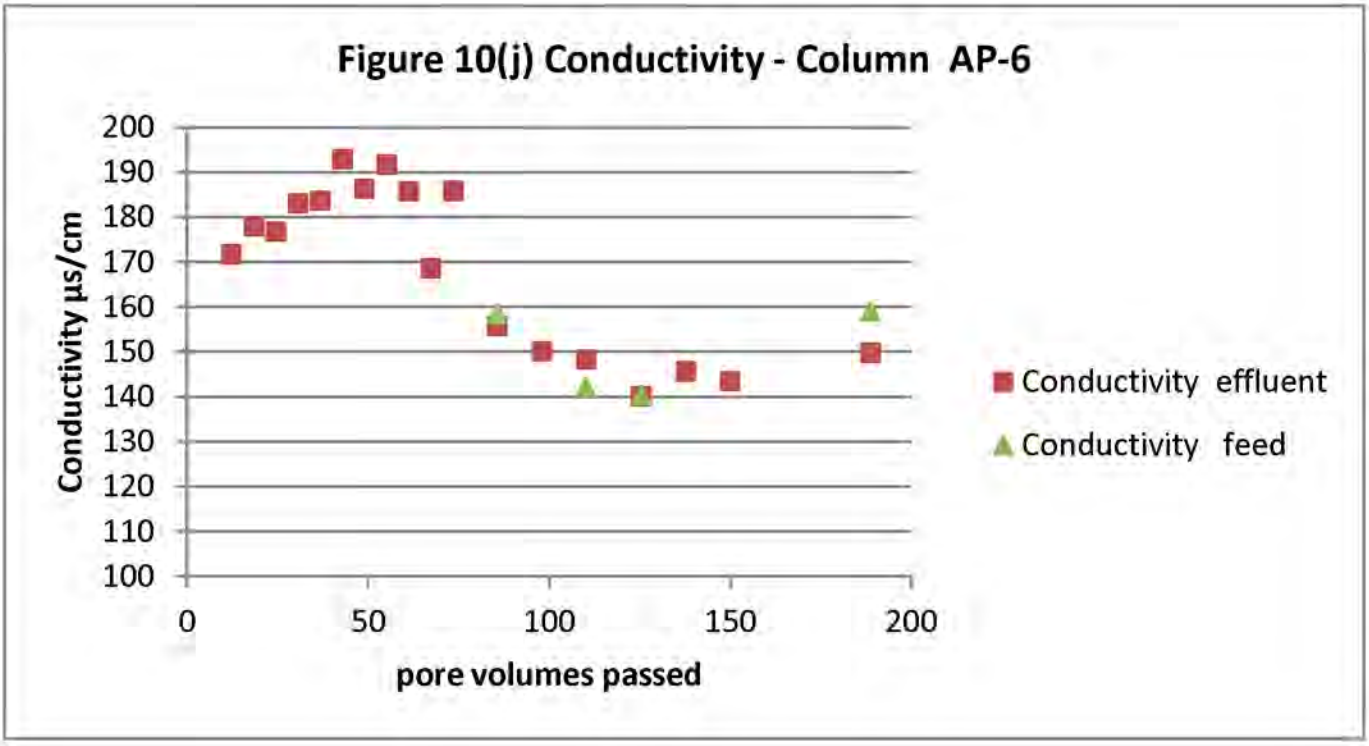


Figure 10(j) Conductivity - Column AP-6
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

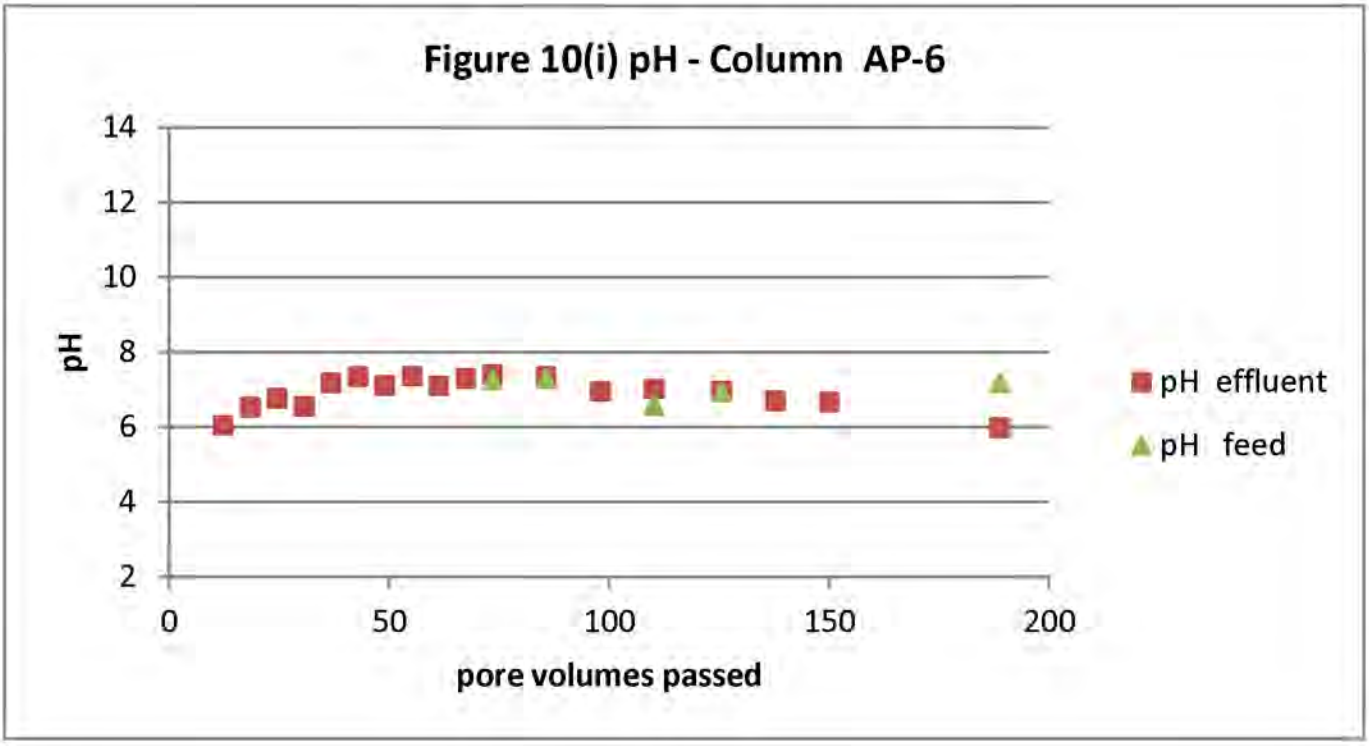


Figure 10(i) pH - Column AP-6
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

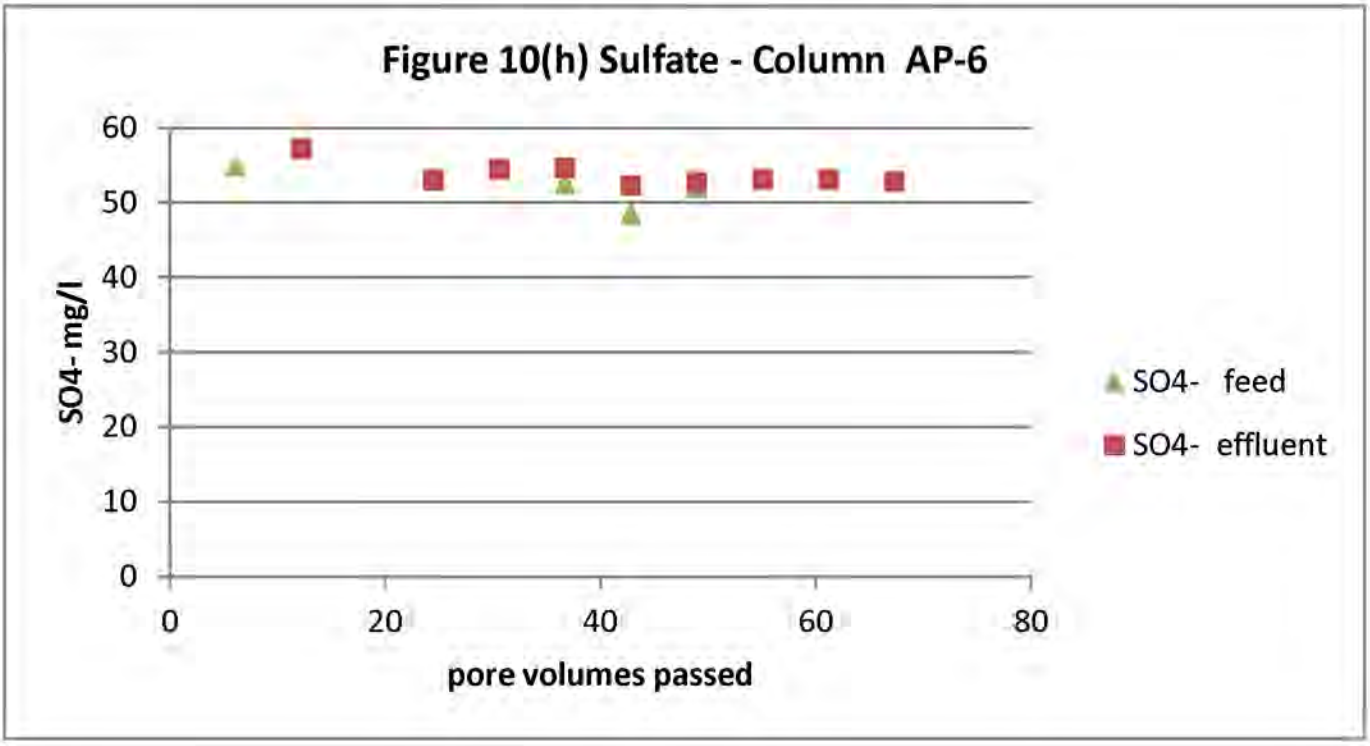


Figure 10(h) Sulfate - Column AP-6
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

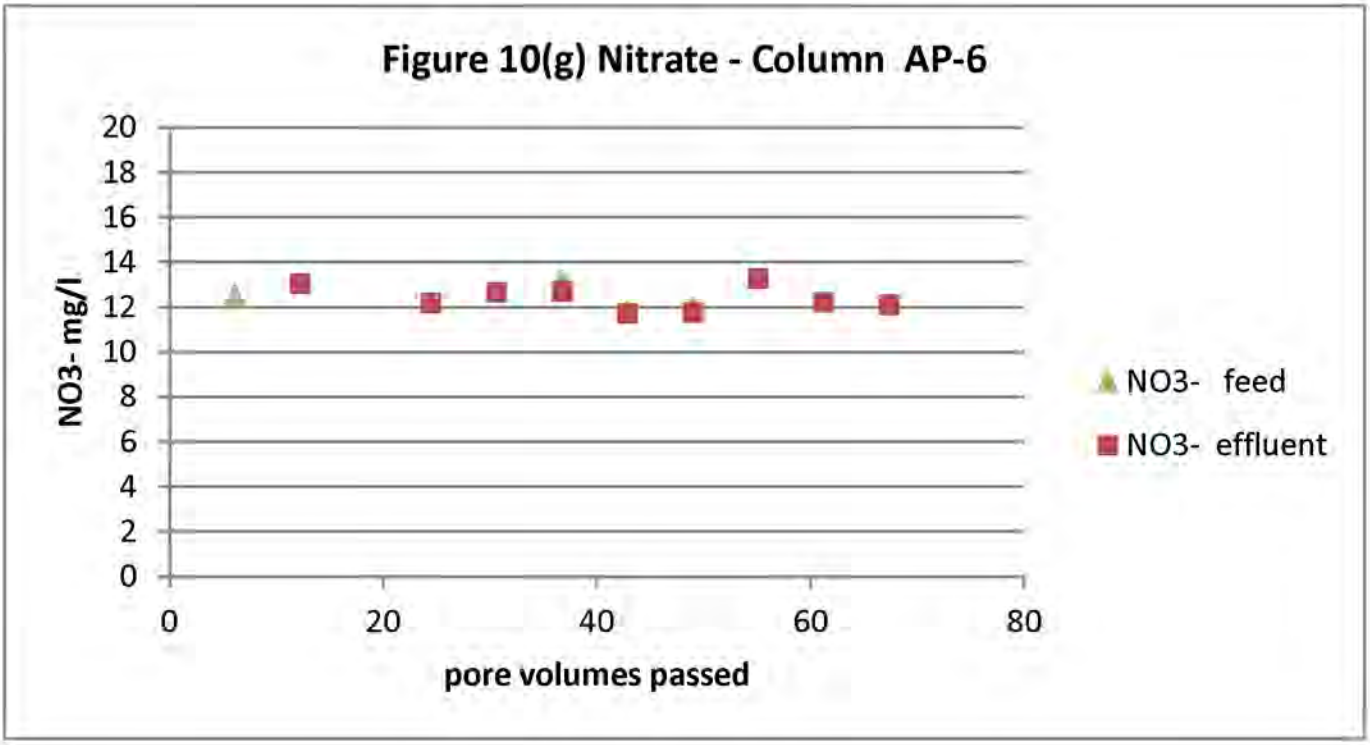


Figure 10(g) Nitrate - Column AP-6
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

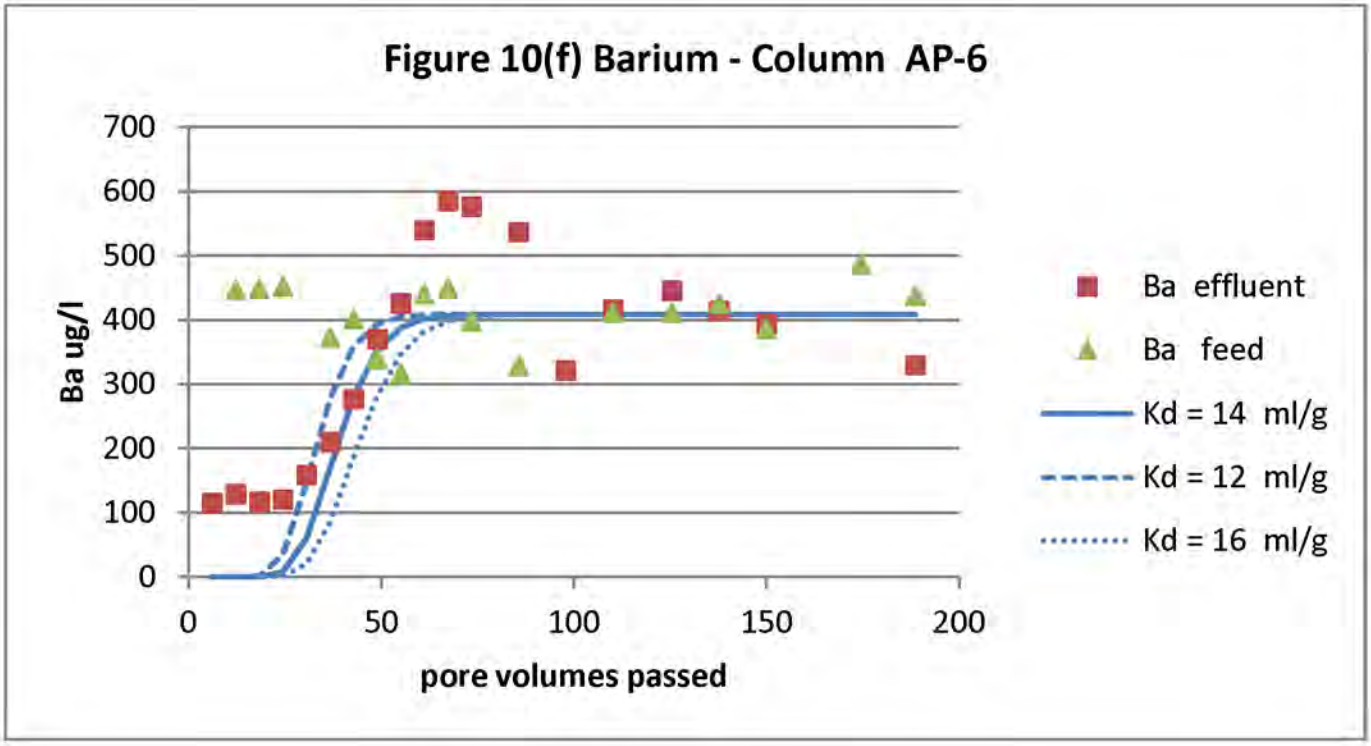


Figure 10(f) Barium - Column AP-6
700
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 14 ml/g
Kd = 12 ml/g
Kd = 16 ml/g

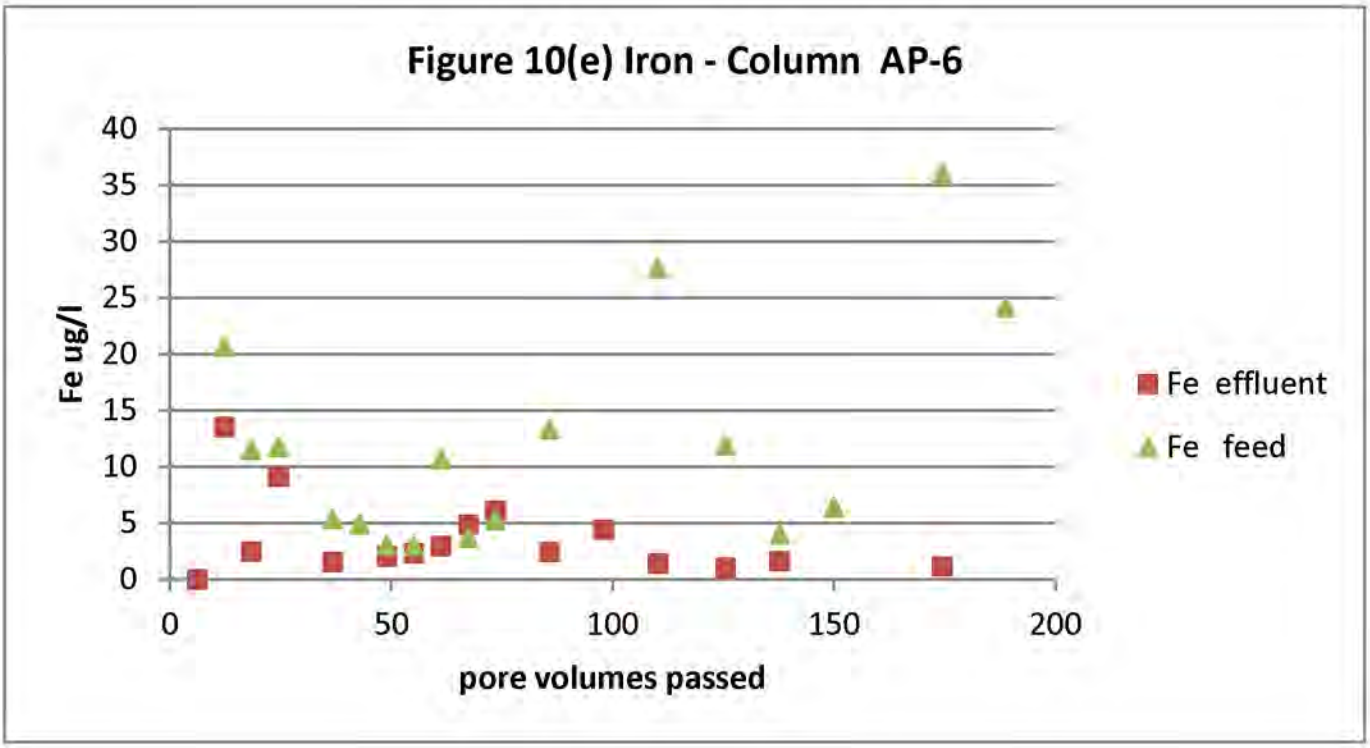


Figure 10(e) Iron - Column AP-6
Fe ug/l
40
35
30
25
20
15
10
5
0
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

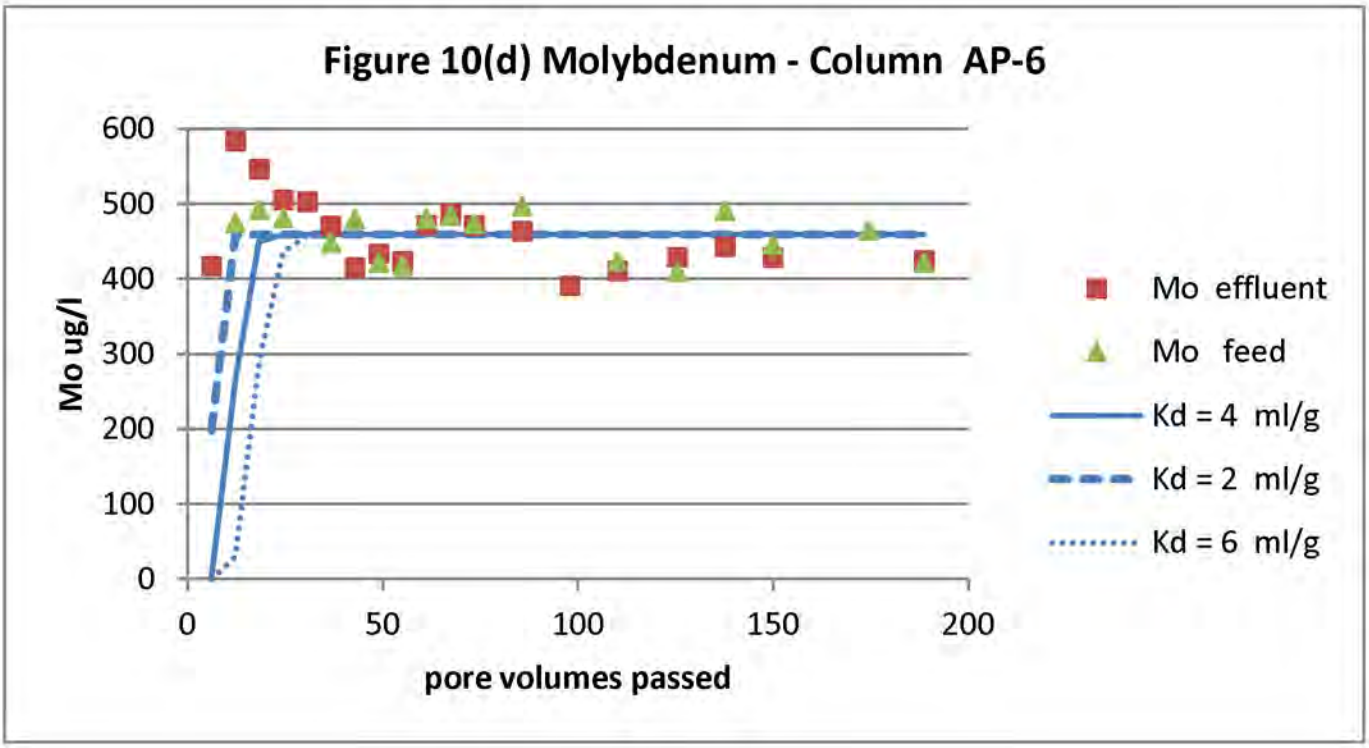


Figure 10(d) Molybdenum - Column AP-6
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 4 ml/g
Kd = 2 ml/g
Kd = 6 ml/g

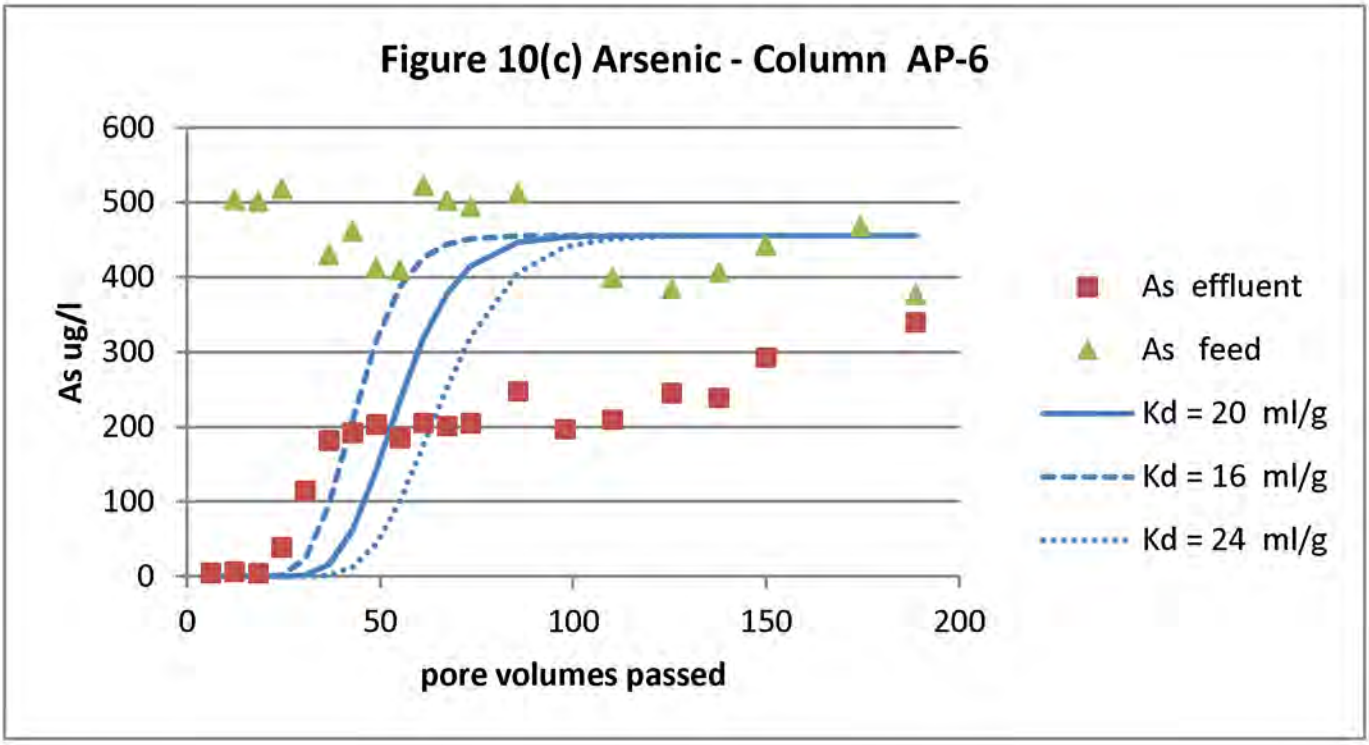


Figure 10(c) Arsenic - Column AP-6
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 20 ml/g
Kd = 16 ml/g
Kd = 24 ml/g

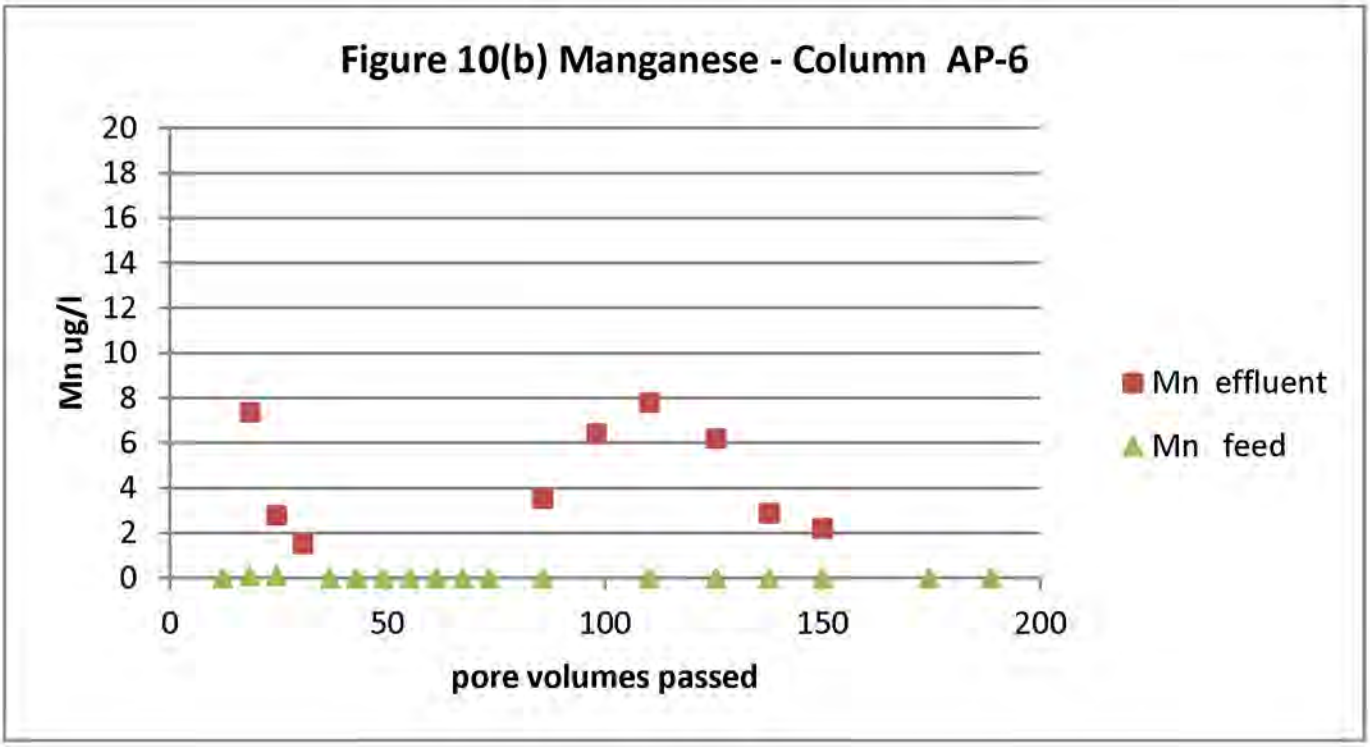


Figure 10(b) Manganese - Column AP-6
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

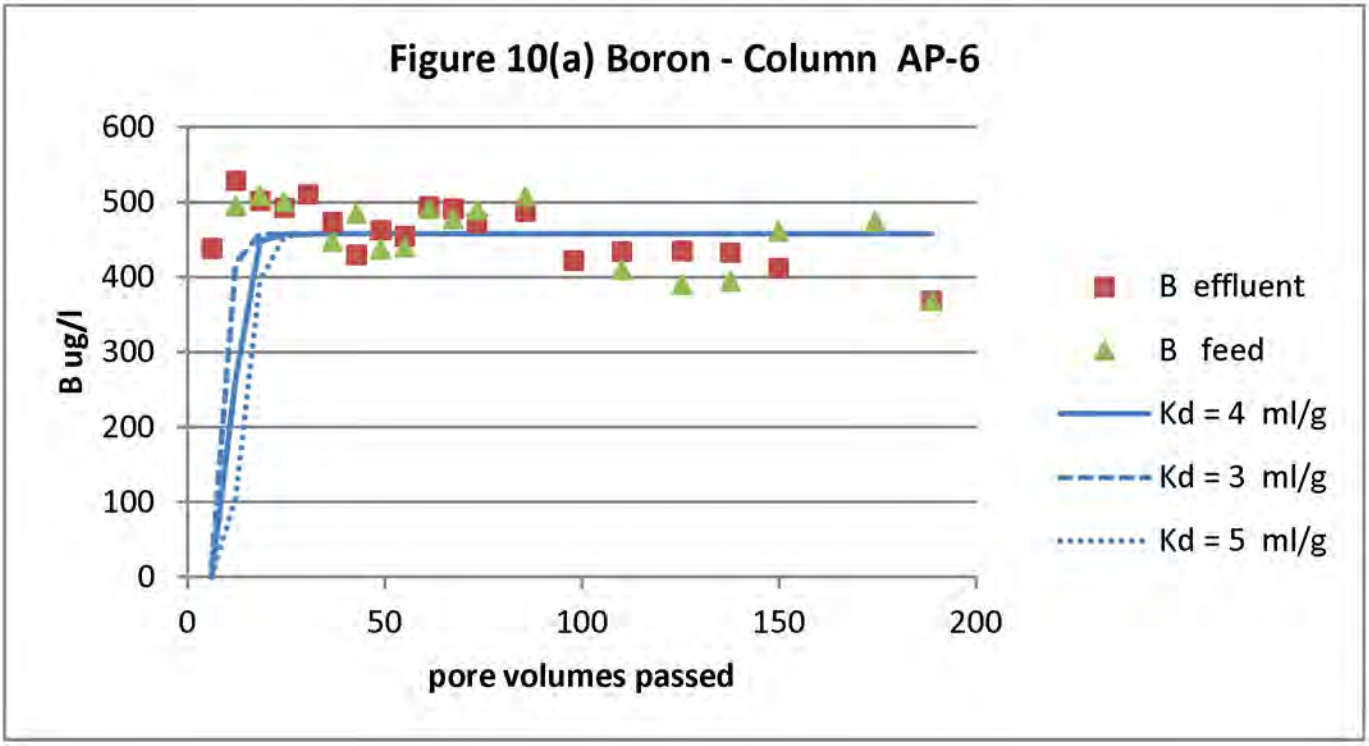


Figure 10(a) Boron - Column AP-6
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 4 ml/g
Kd = 3 ml/g
Kd = 5 ml/g

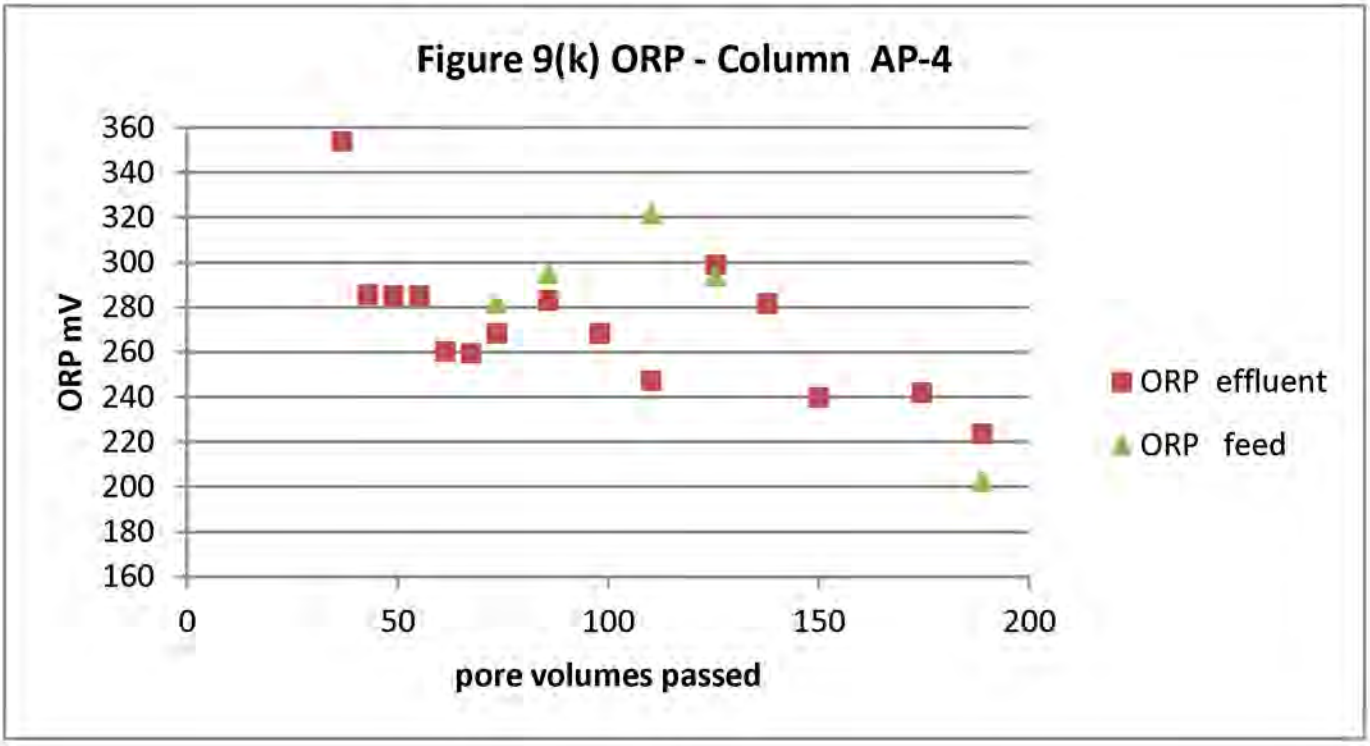


Figure 9(k) ORP - Column AP-4
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

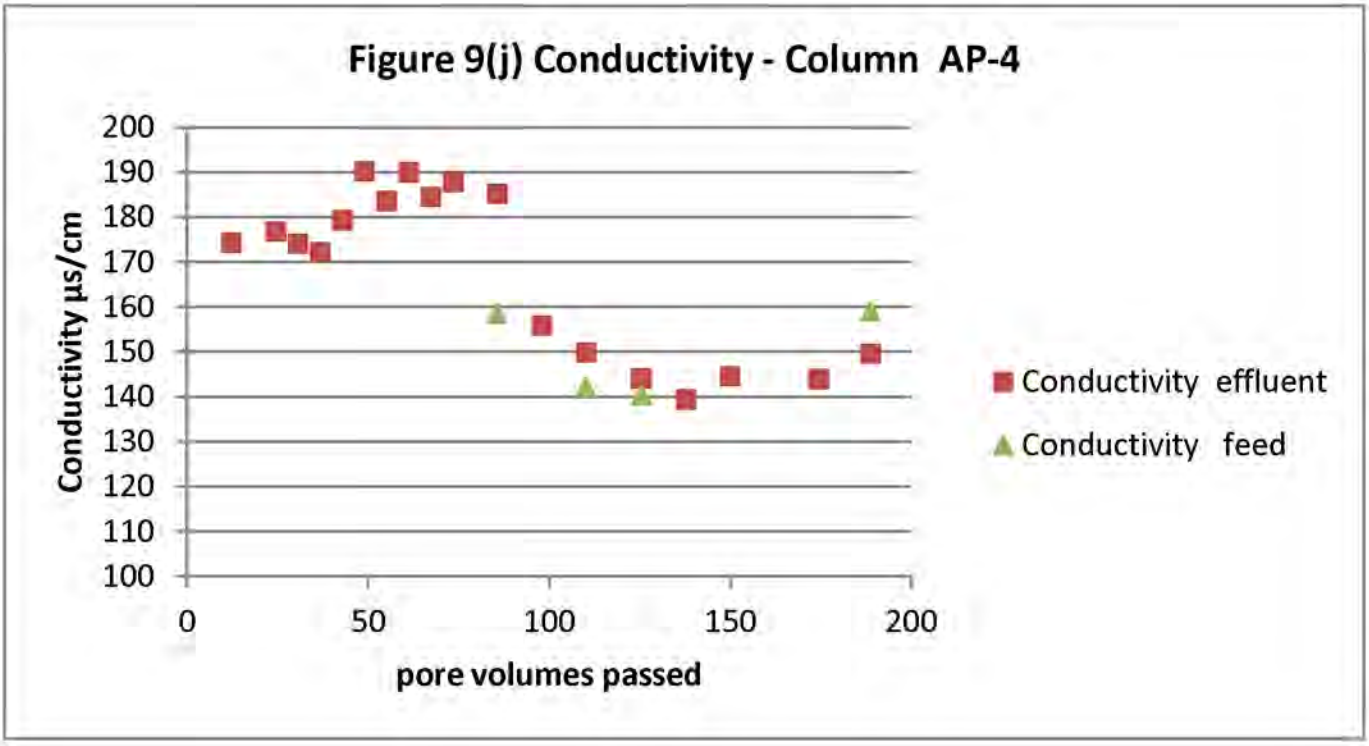


Figure 9(j) Conductivity - Column AP-4
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

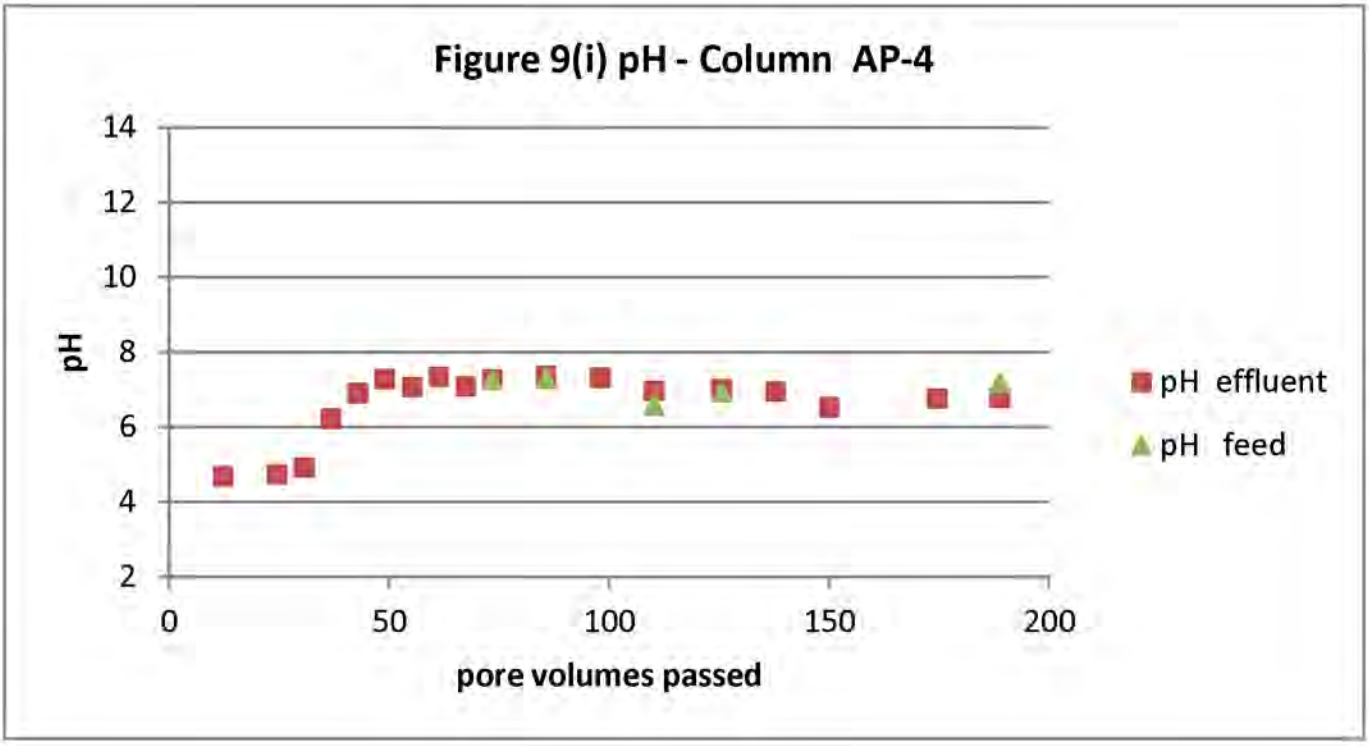


Figure 9(i) pH - Column AP-4
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

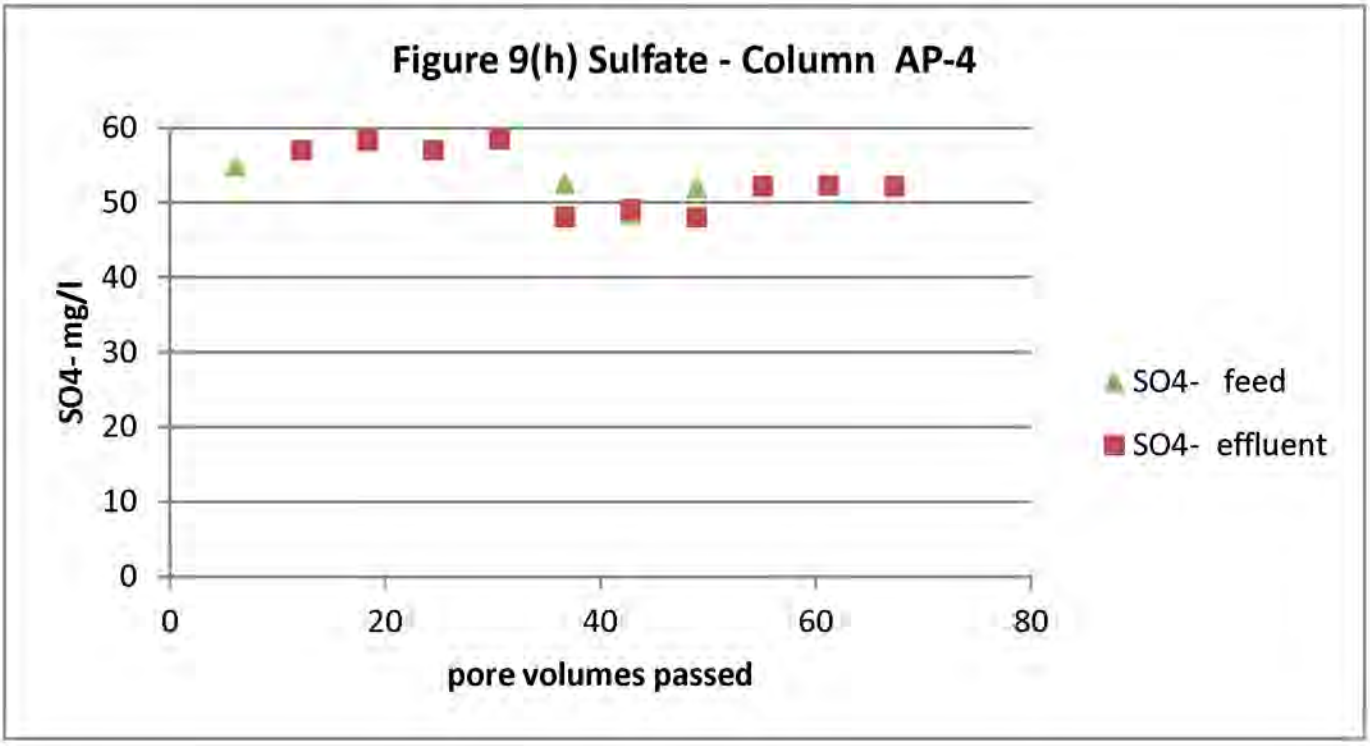


Figure 9(h) Sulfate - Column AP-4
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

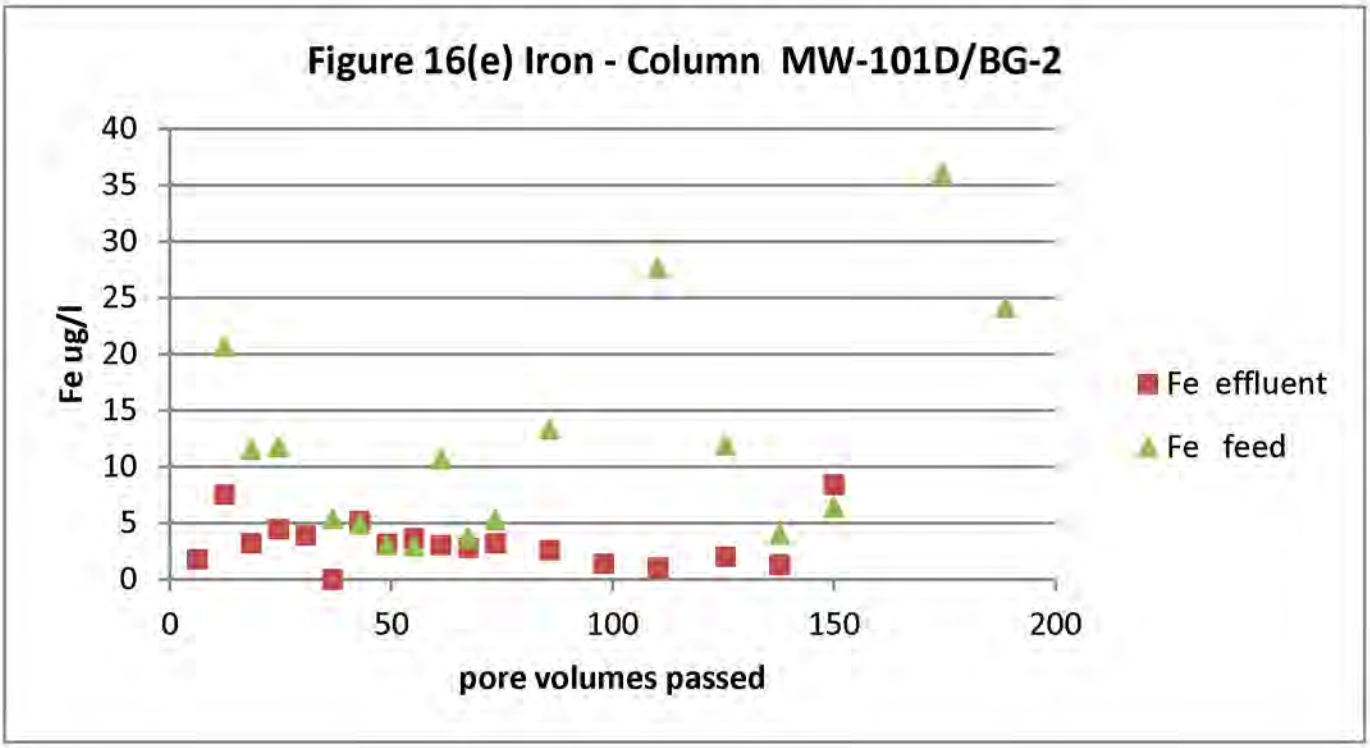


Figure 16(e) Iron - Column MW-101D/BG-2
Fe ug/l
40
35
30
25
20
15
10
5
0
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

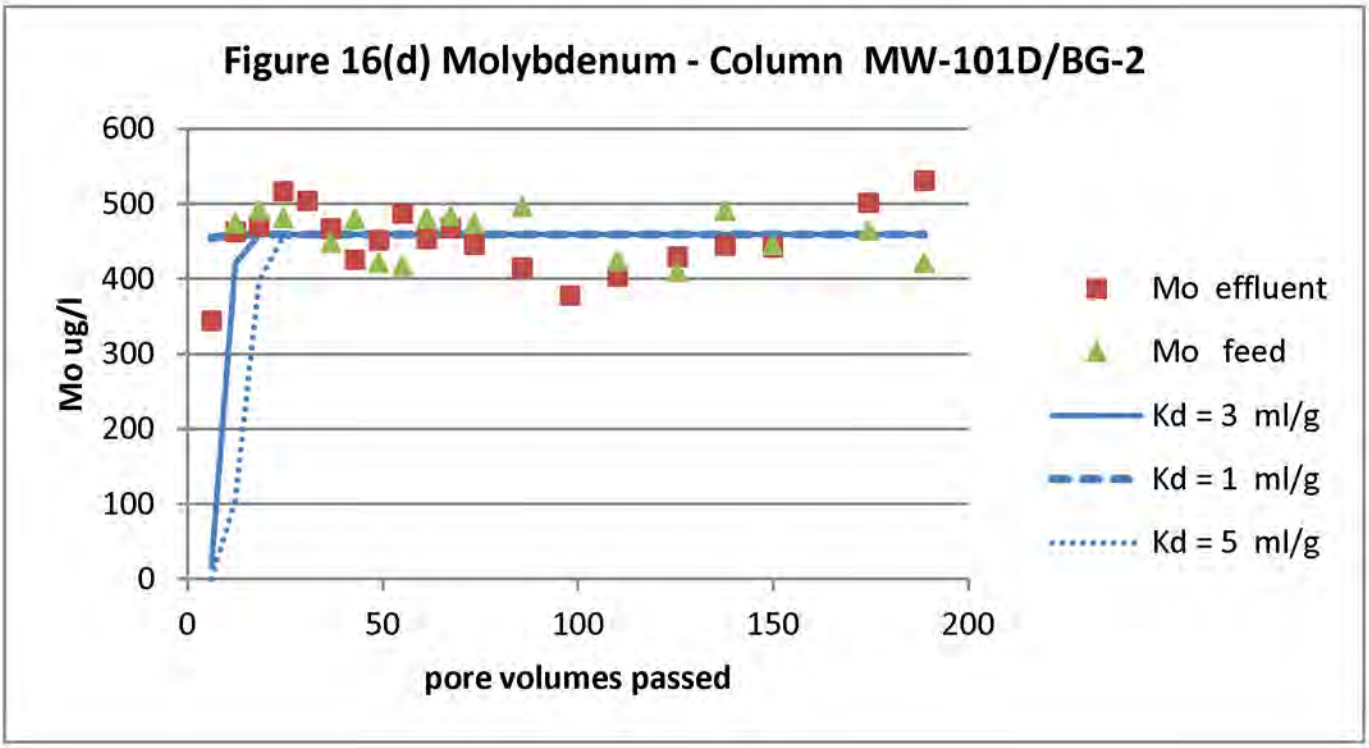


Figure 16(d) Molybdenum - Column MW-101D/BG-2
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 3 ml/g
Kd = 1 ml/g
Kd = 5 ml/g

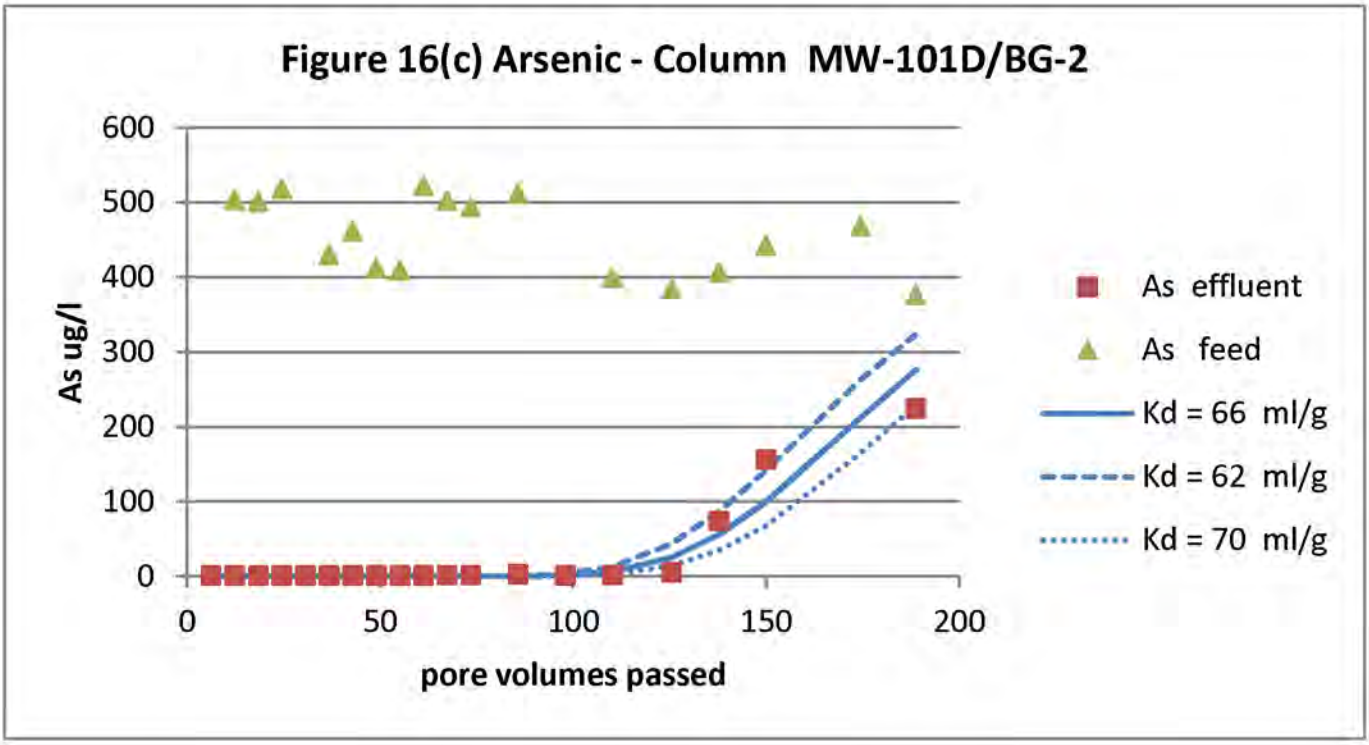


Figure 16(c) Arsenic - Column MW-101D/BG-2
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 66 ml/g
Kd = 62 ml/g
Kd = 70 ml/g

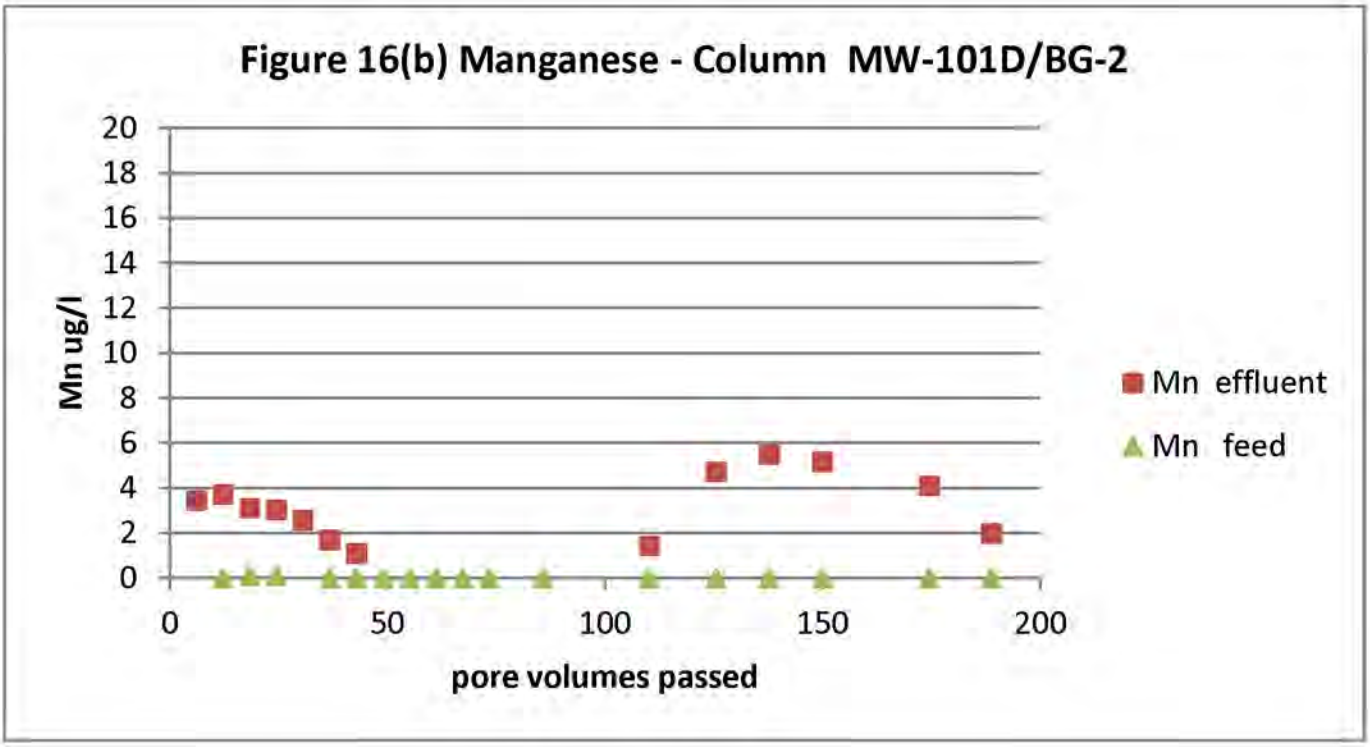


Figure 16(b) Manganese - Column MW-101D/BG-2
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

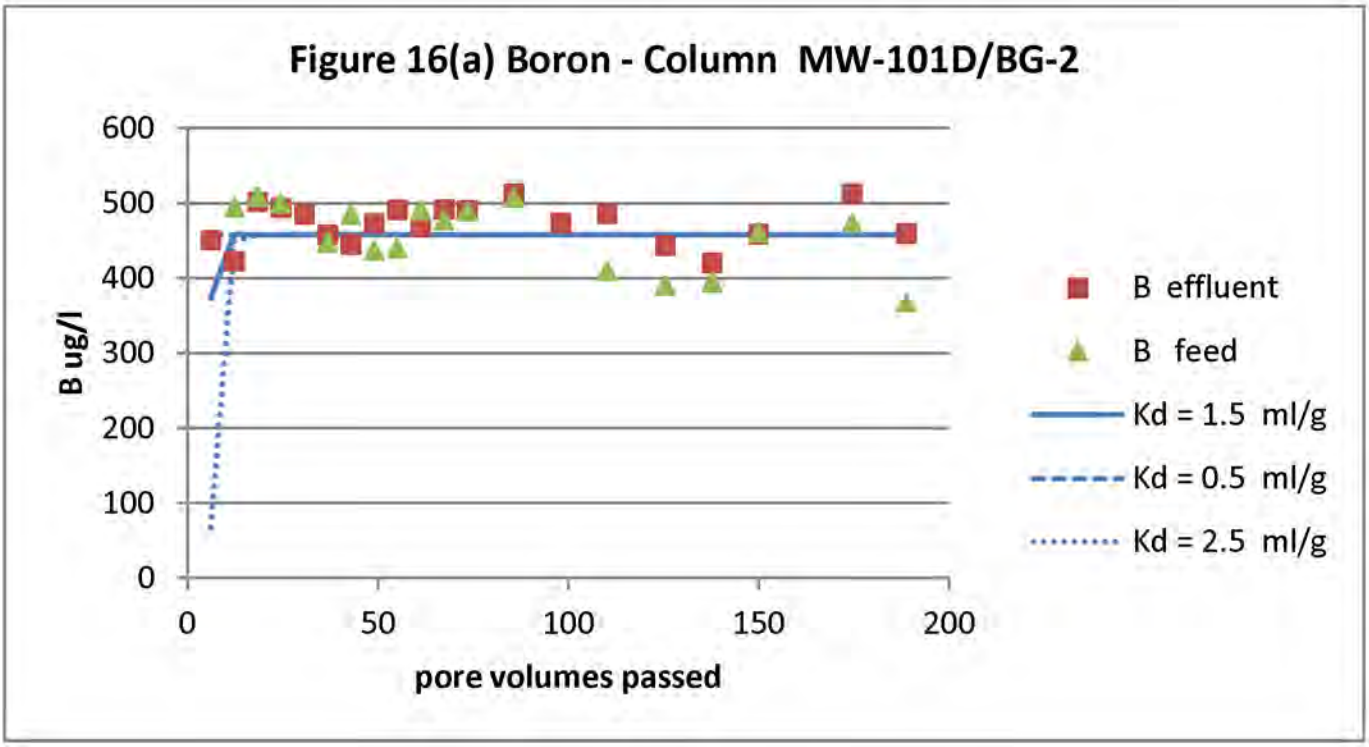


Figure 16(a) Boron - Column MW-101D/BG-2
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 1.5 ml/g
Kd = 0.5 ml/g
Kd = 2.5 ml/g

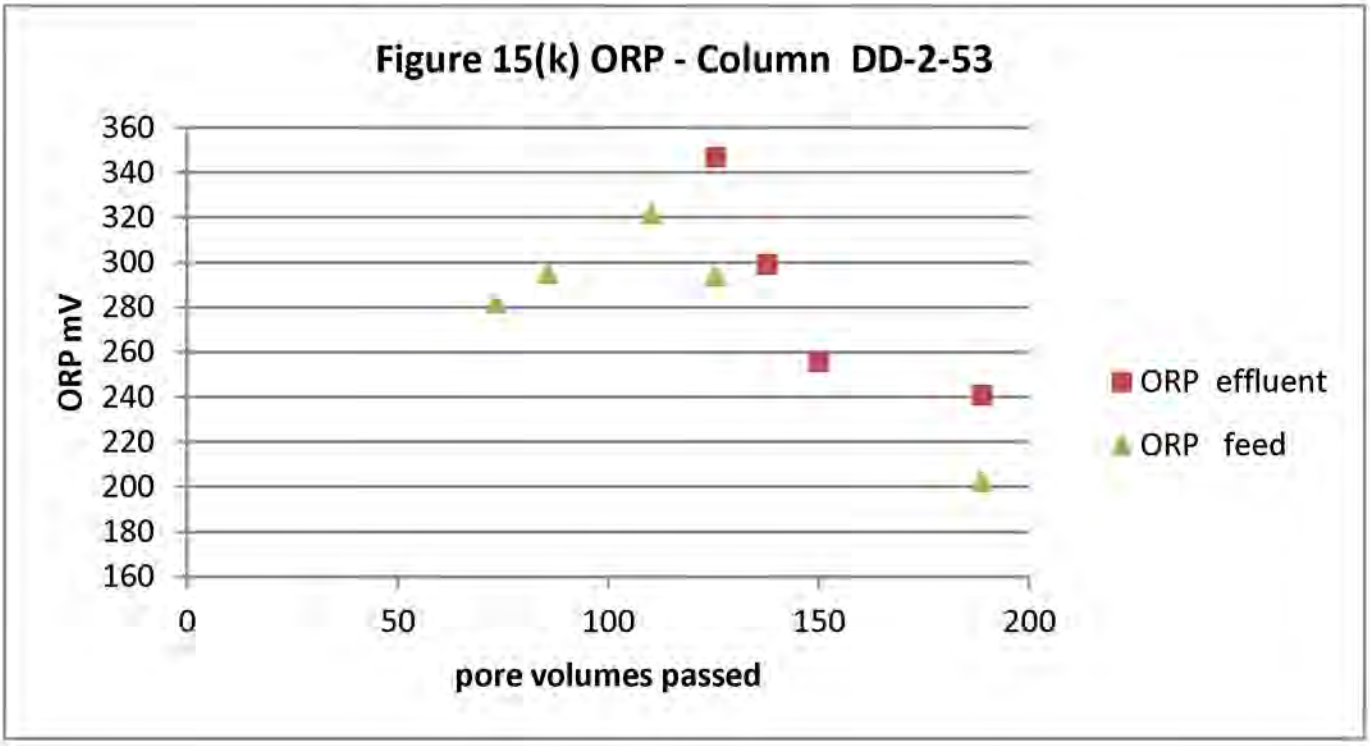


Figure 15(k) ORP - Column DD-2-53
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

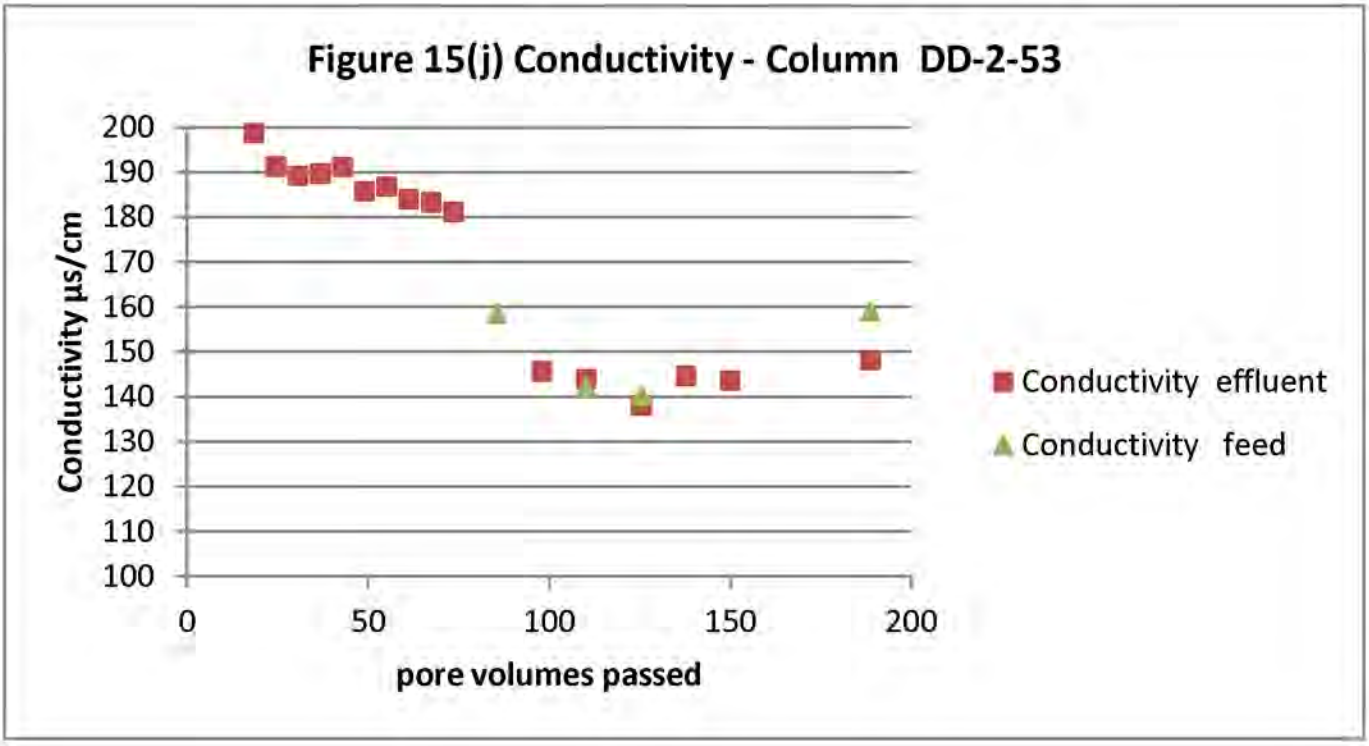


Figure 15(j) Conductivity - Column DD-2-53
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

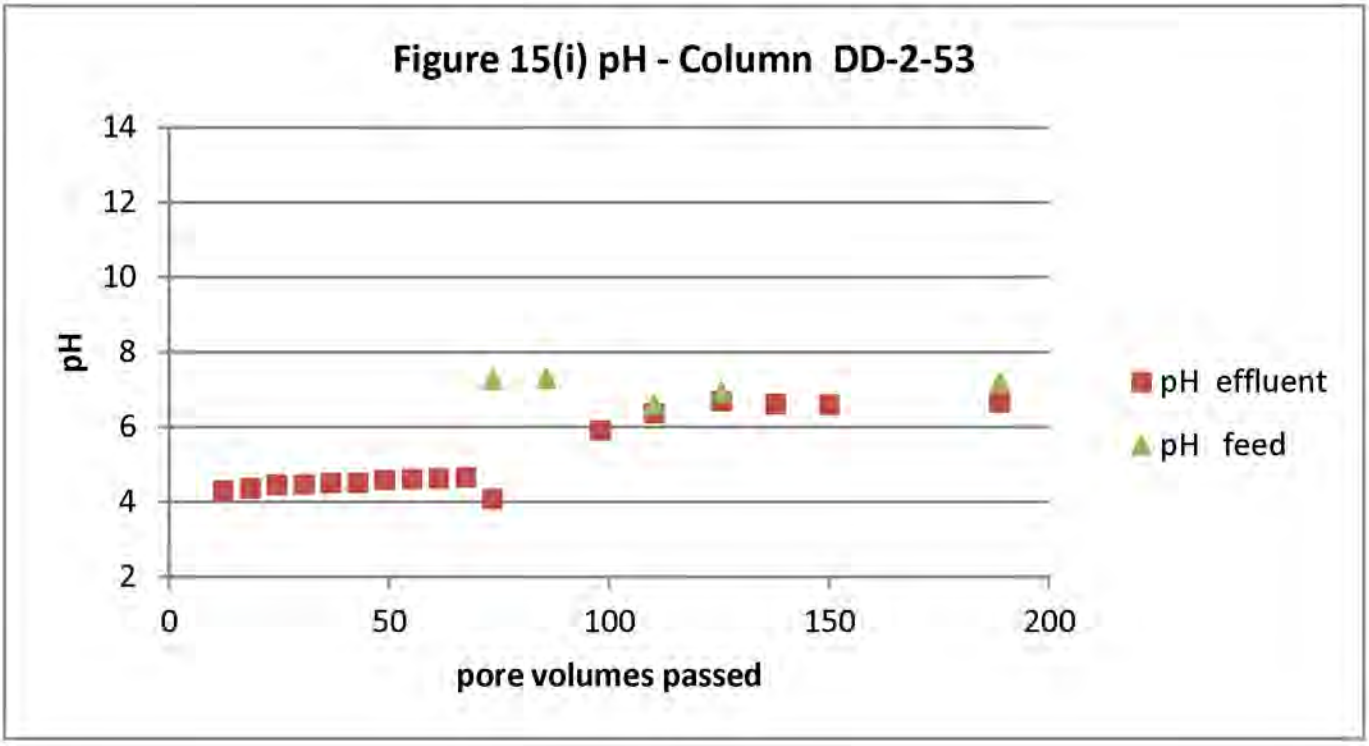


Figure 15(i) pH - Column DD-2-53
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

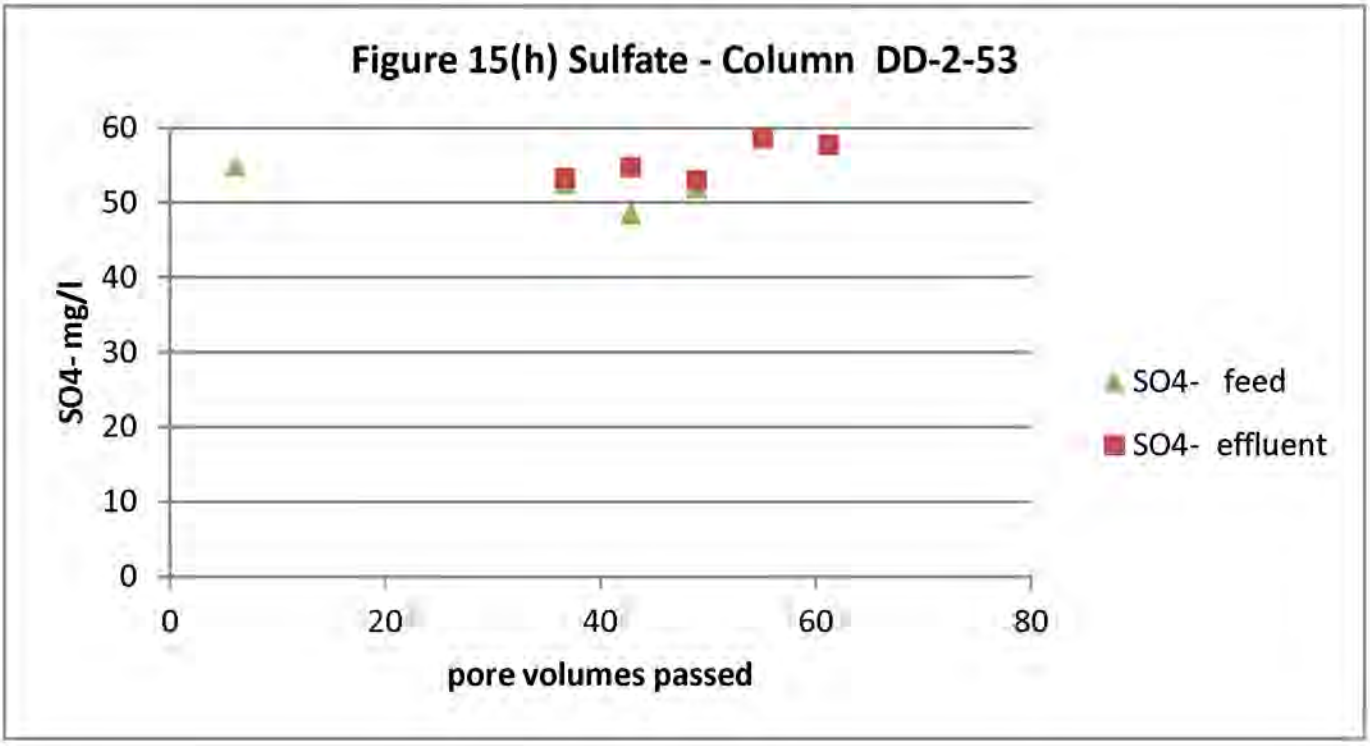


Figure 15(h) Sulfate - Column DD-2-53
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

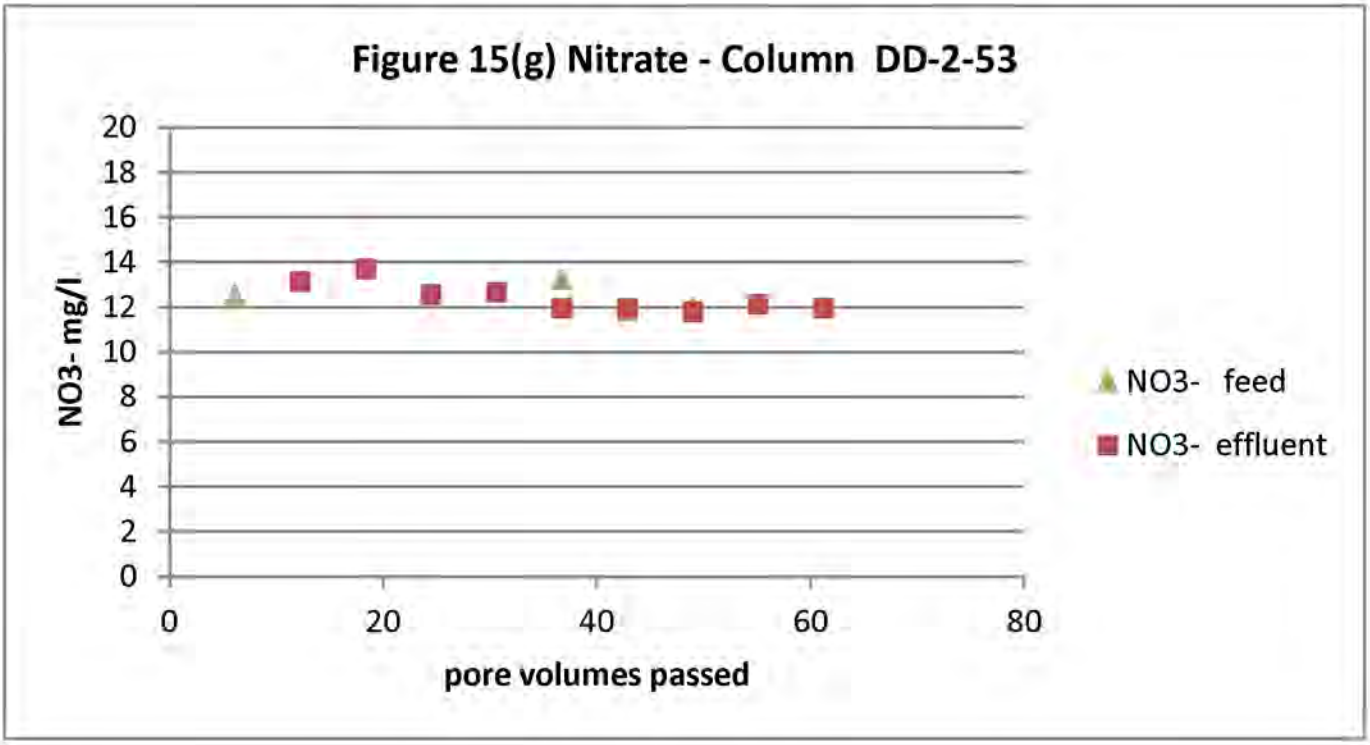


Figure 15(g) Nitrate - Column DD-2-53
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

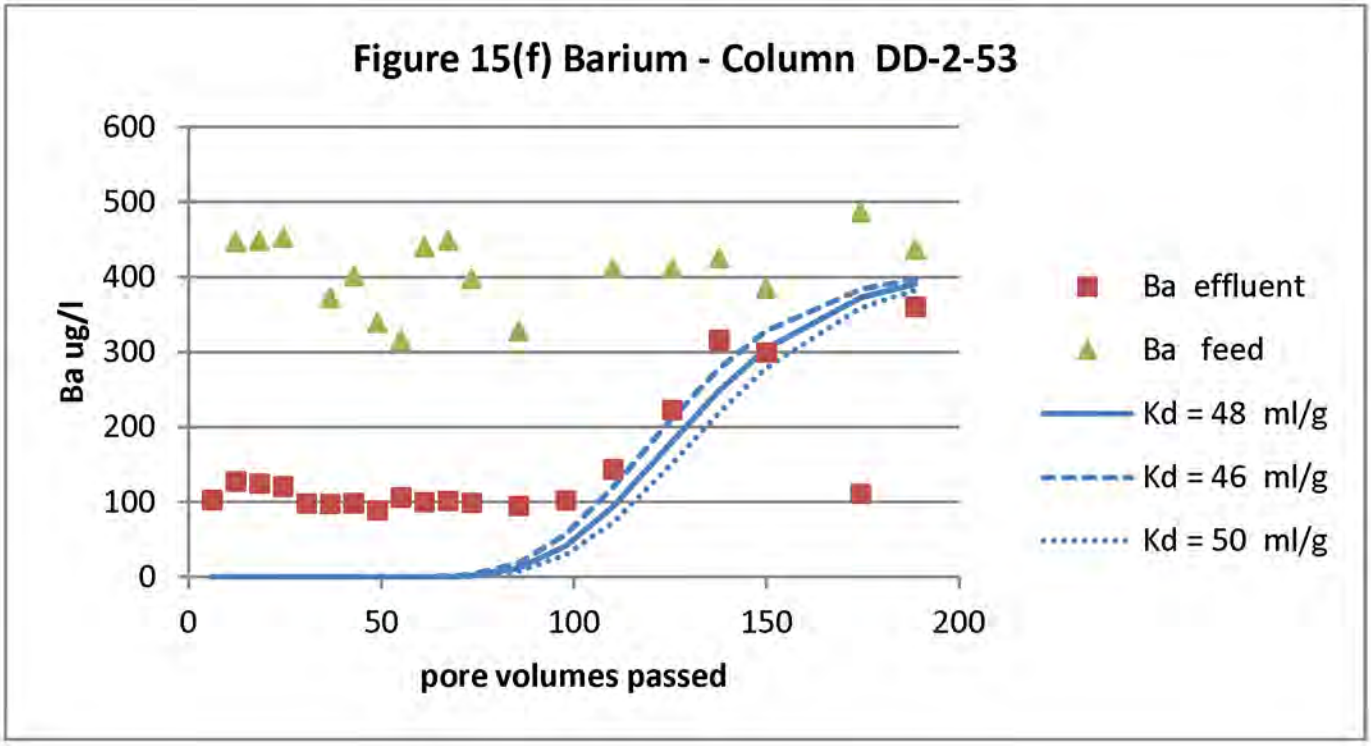


Figure 15(f) Barium - Column DD-2-53
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 48 ml/g
Kd = 46 ml/g
Kd = 50 ml/g

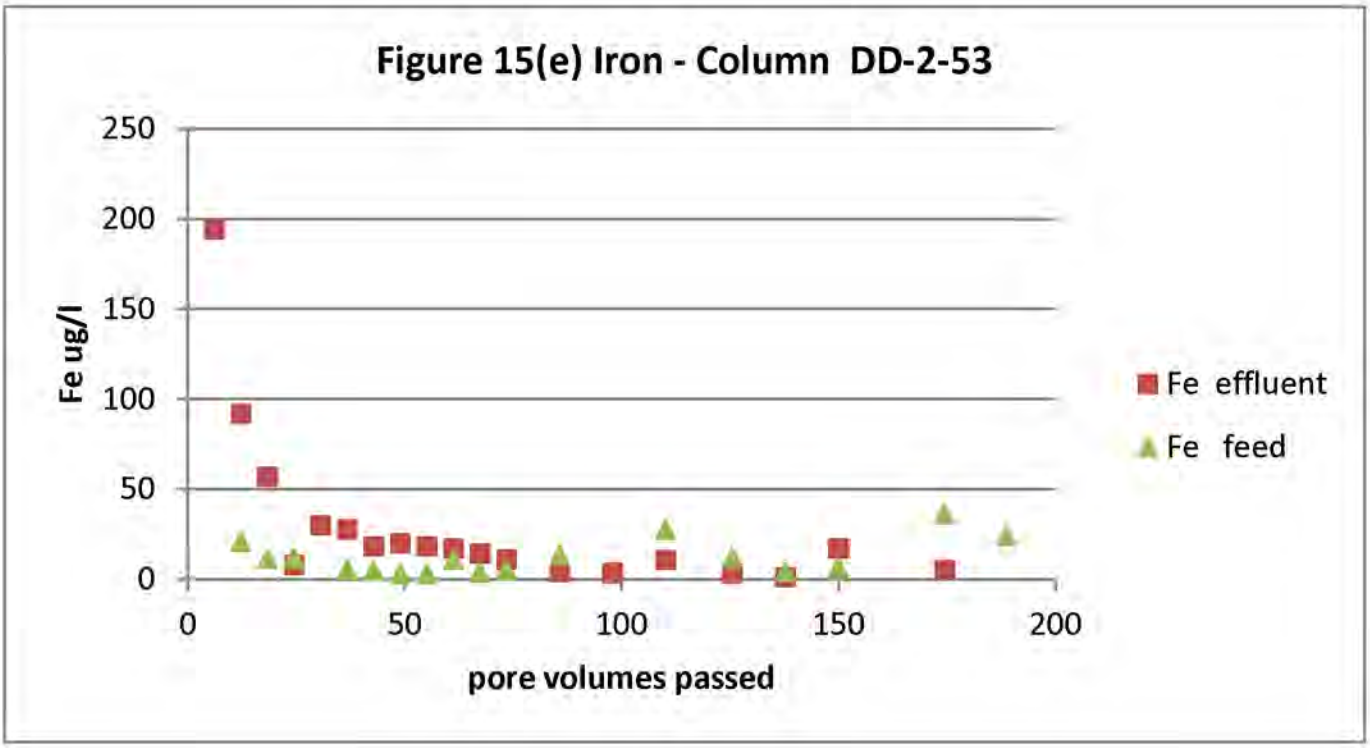


Figure 15(e) Iron - Column DD-2-53
250
200
150
100
50
0
Fe ug/l
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

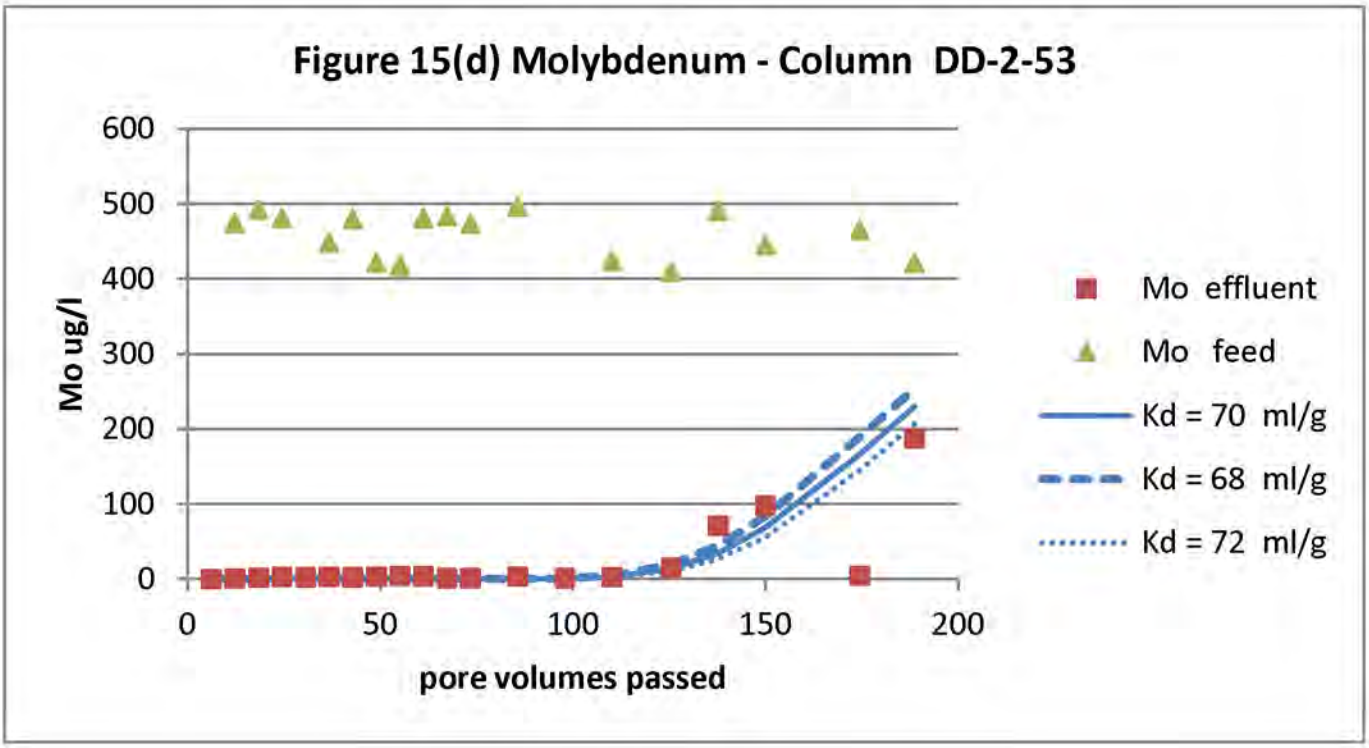


Figure 15(d) Molybdenum - Column DD-2-53
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 70 ml/g
Kd = 68 ml/g
Kd = 72 ml/g

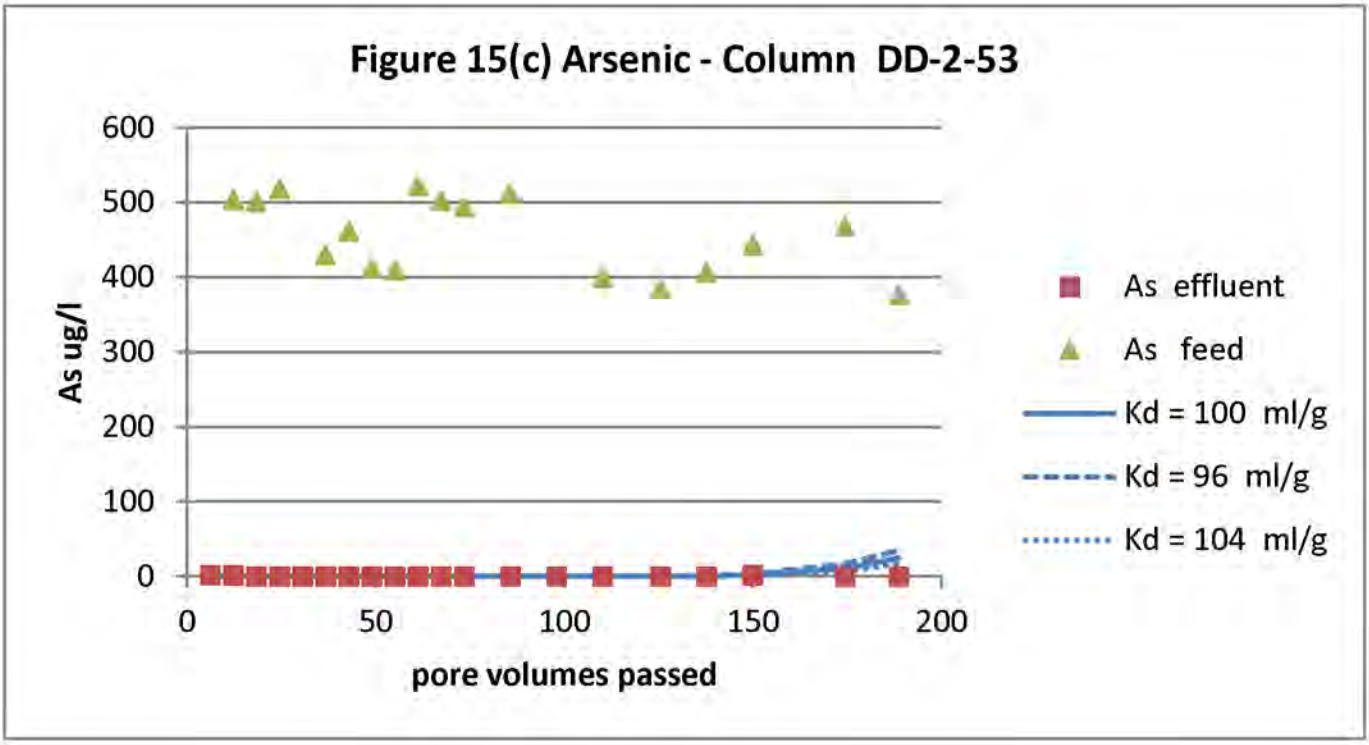


Figure 15(c) Arsenic - Column DD-2-53
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 100 ml/g
Kd = 96 ml/g
Kd = 104 ml/g

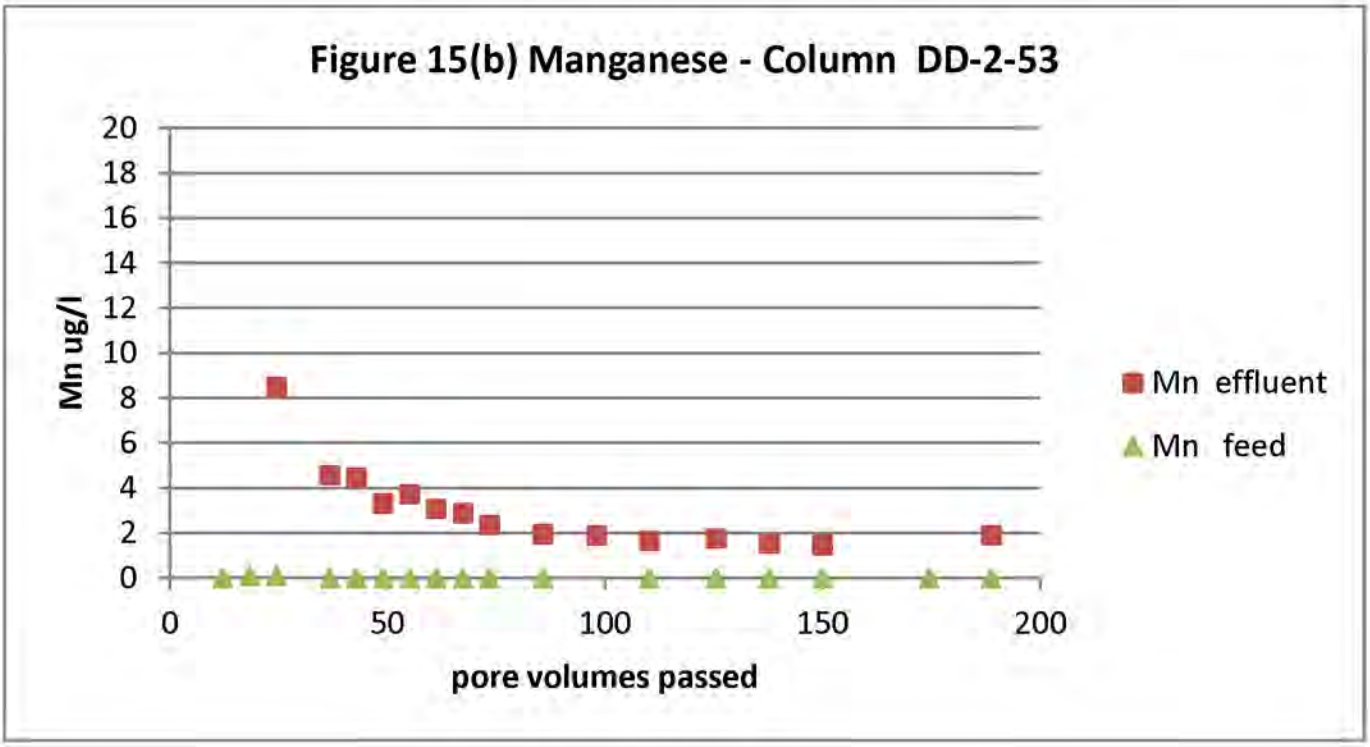


Figure 15(b) Manganese - Column DD-2-53
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

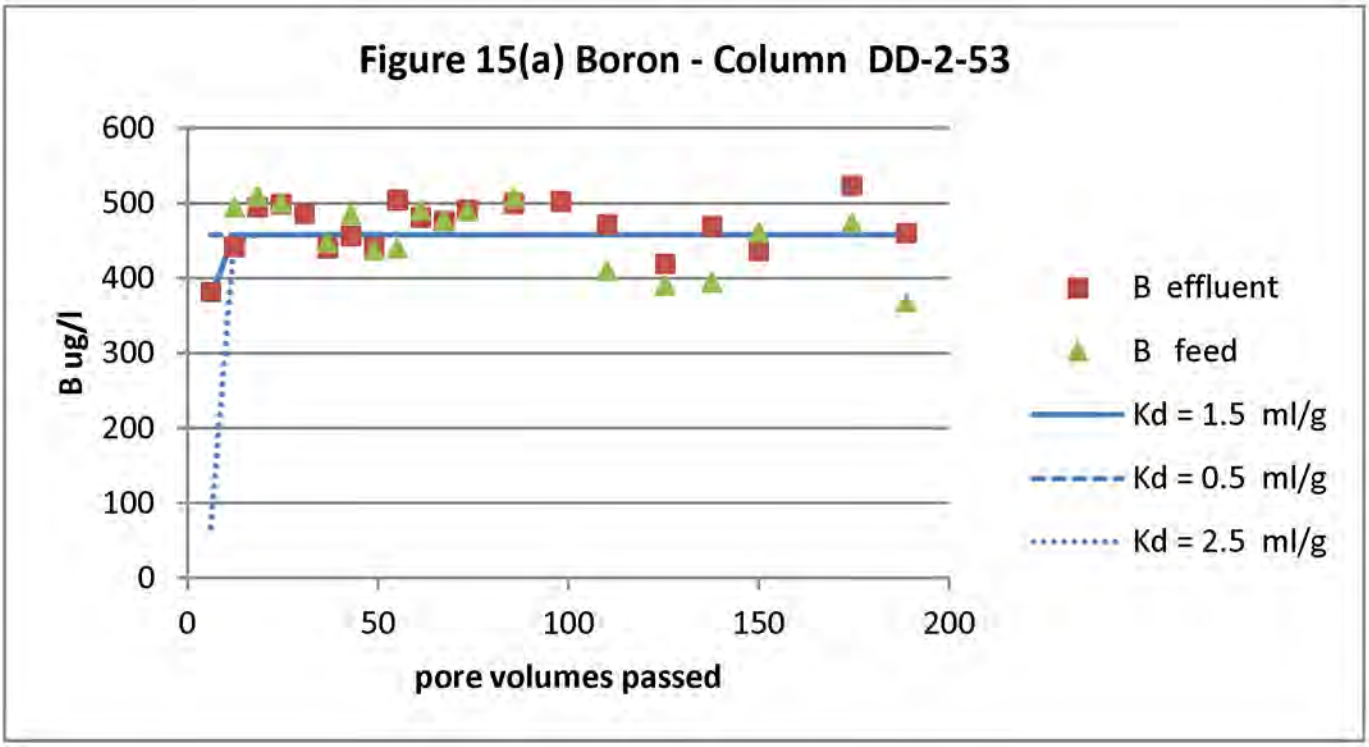


Figure 15(a) Boron - Column DD-2-53
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 1.5 ml/g
Kd = 0.5 ml/g
Kd = 2.5 ml/g

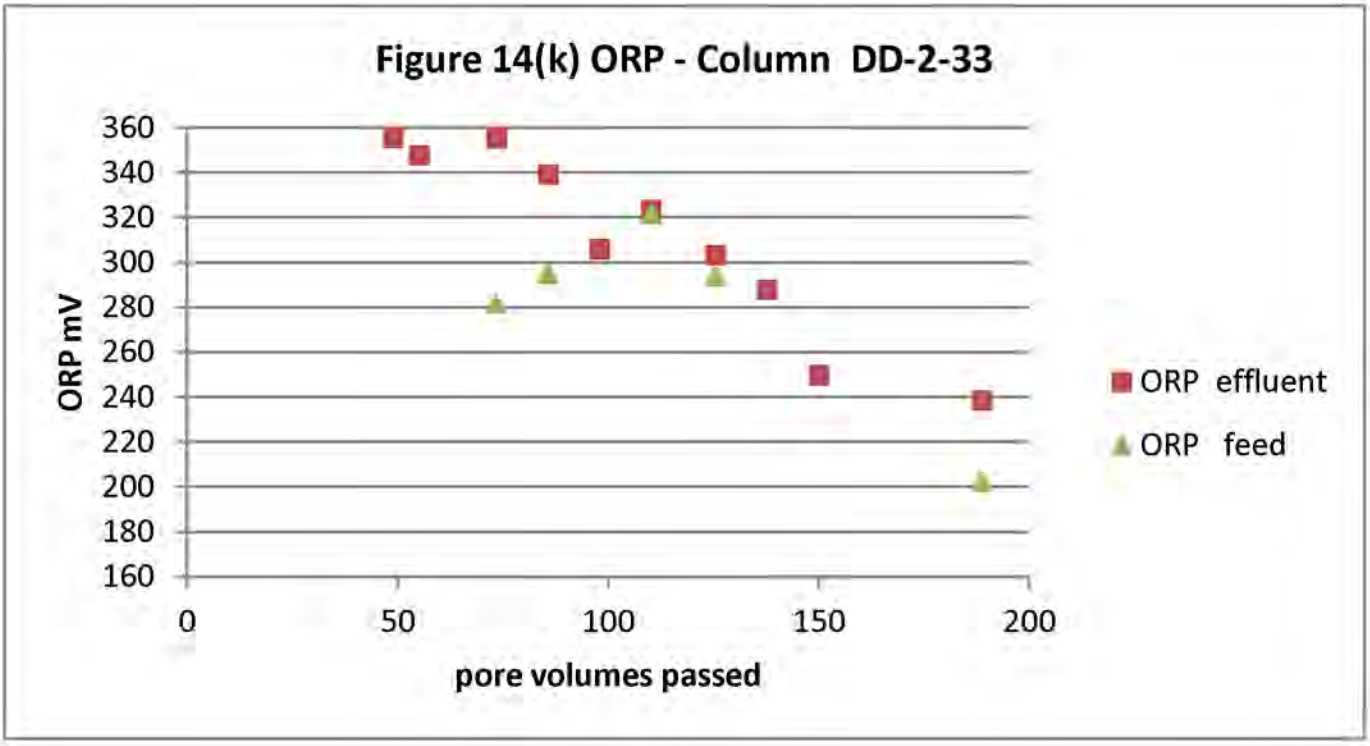


Figure 14(k) ORP - Column DD-2-33
ORP mV
360
340
320
300
280
260
240
220
200
180
160
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

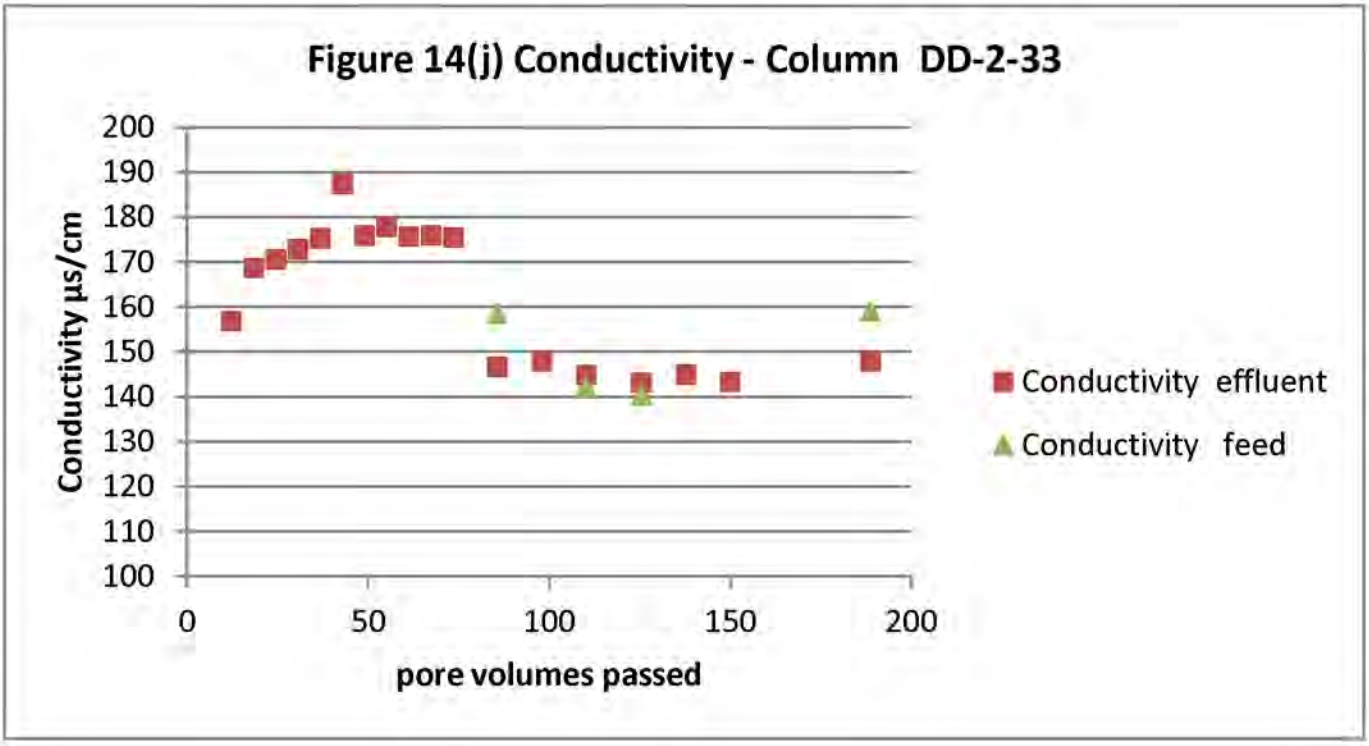


Figure 14(j) Conductivity - Column DD-2-33
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

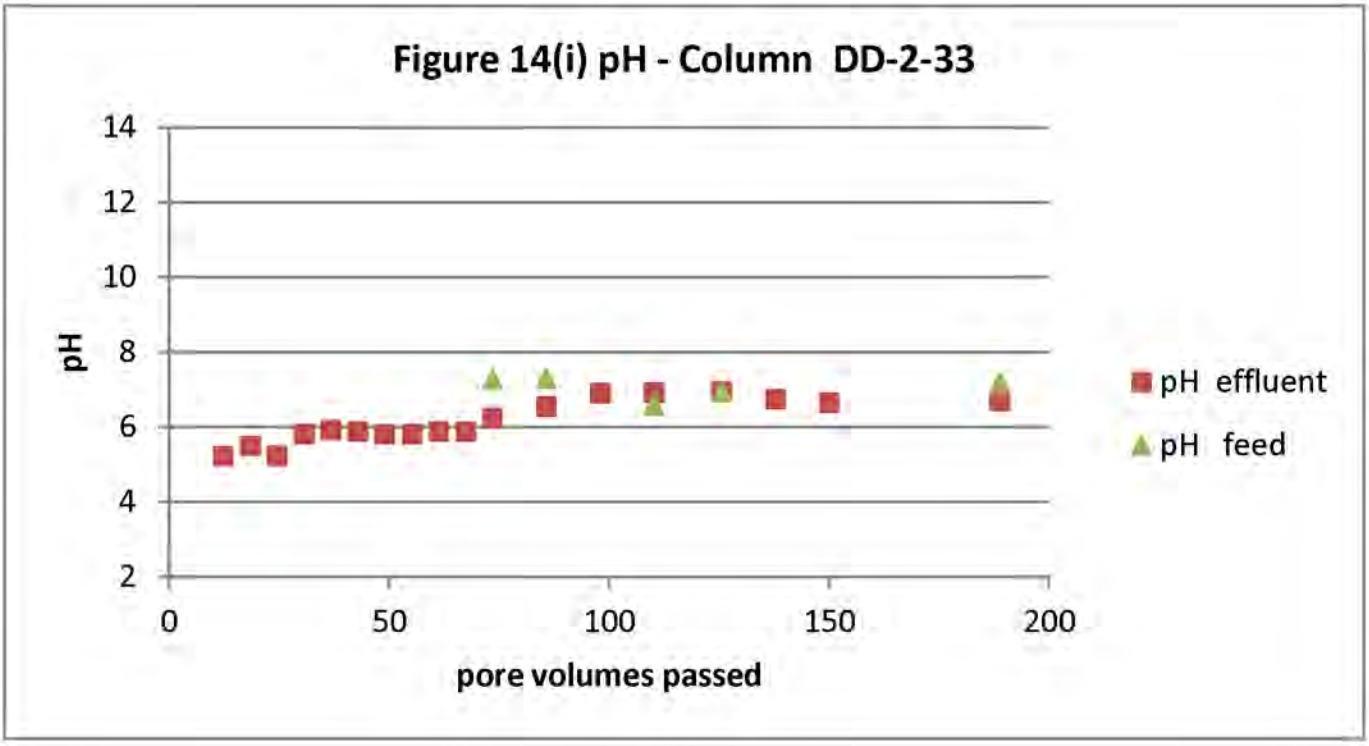


Figure 14(i) pH - Column DD-2-33
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

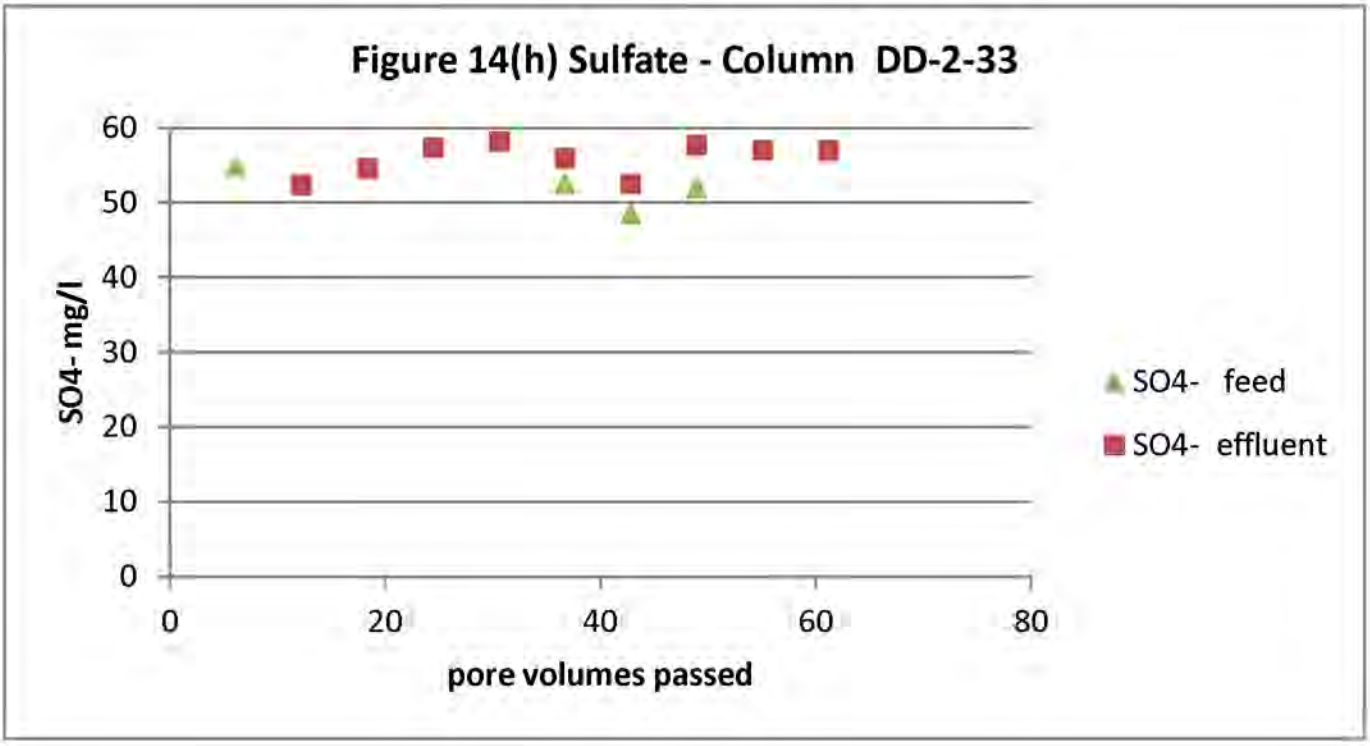


Figure 14(h) Sulfate - Column DD-2-33
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

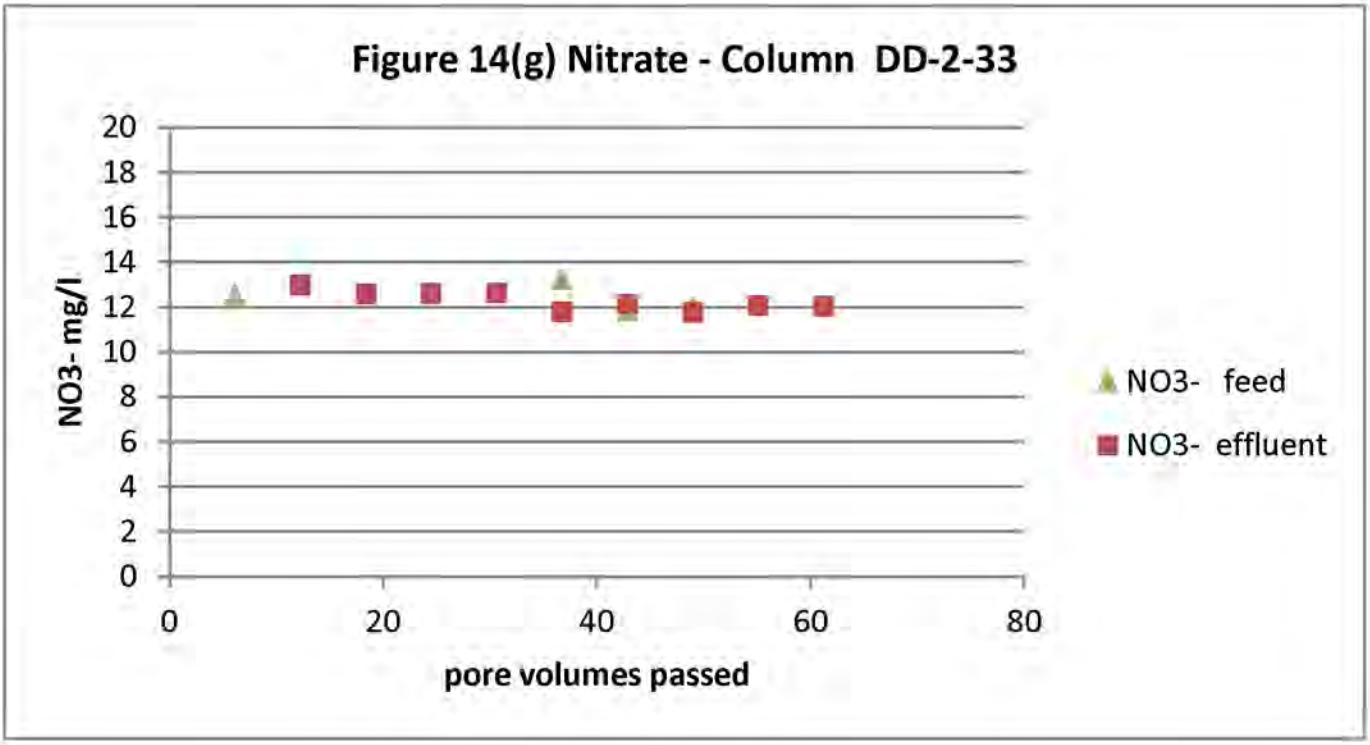


Figure 14(g) Nitrate - Column DD-2-33
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

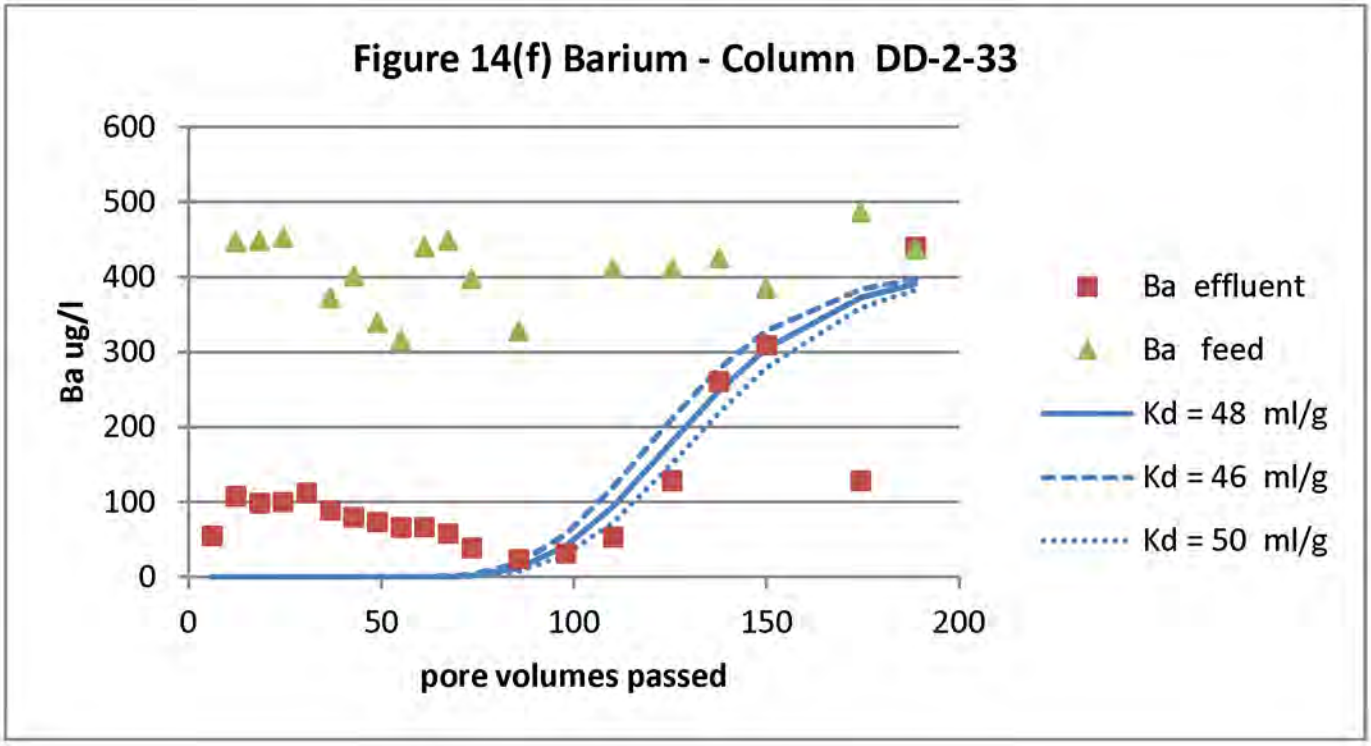


Figure 14(f) Barium - Column DD-2-33
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 48 ml/g
Kd = 46 ml/g
Kd = 50 ml/g

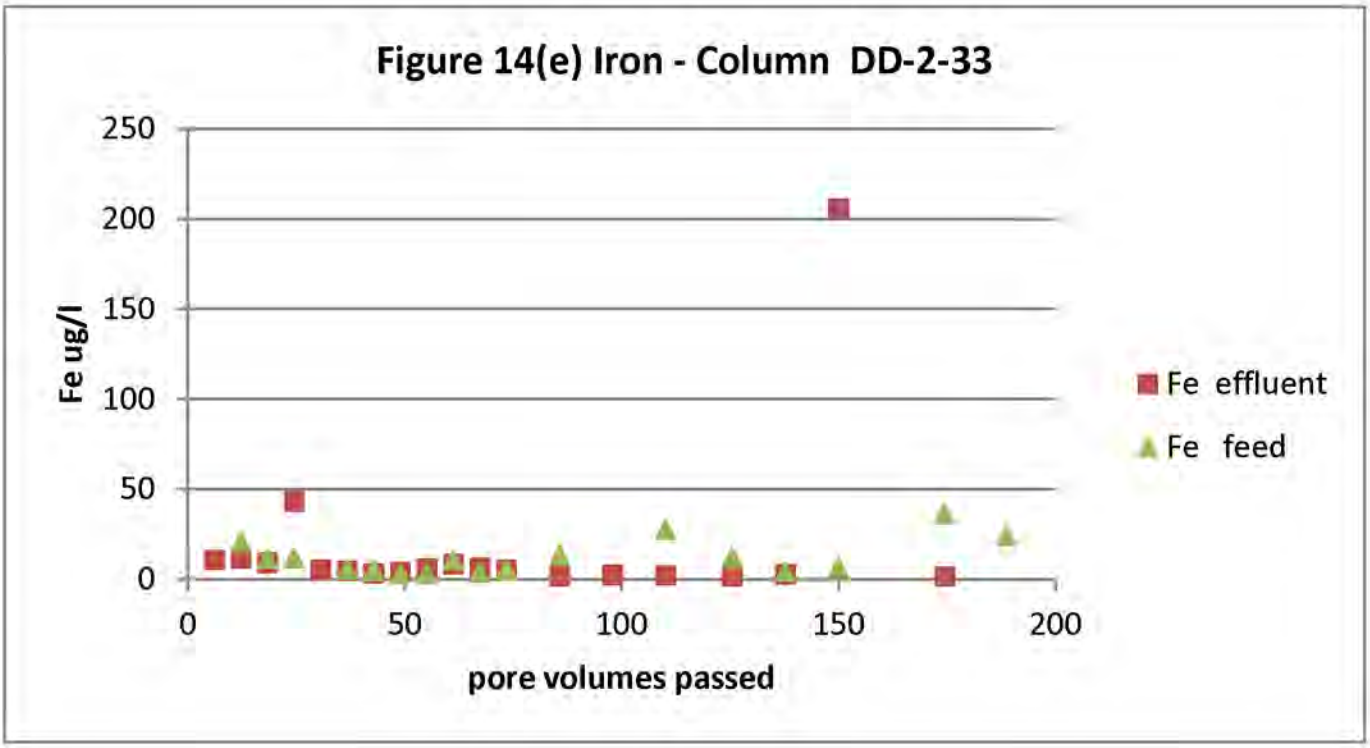


Figure 14(e) Iron - Column DD-2-33
250
200
150
100
50
0
Fe ug/l
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

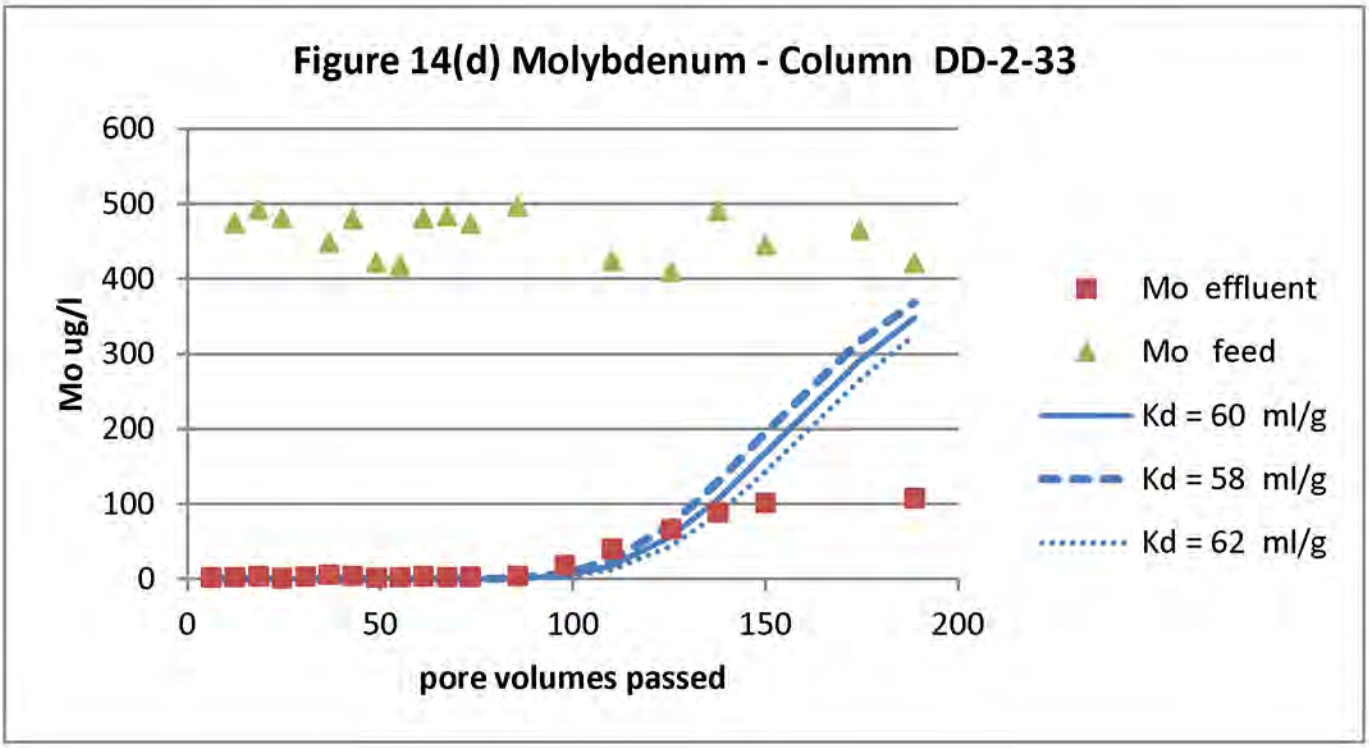


Figure 14(d) Molybdenum - Column DD-2-33
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 60 ml/g
Kd = 58 ml/g
Kd = 62 ml/g

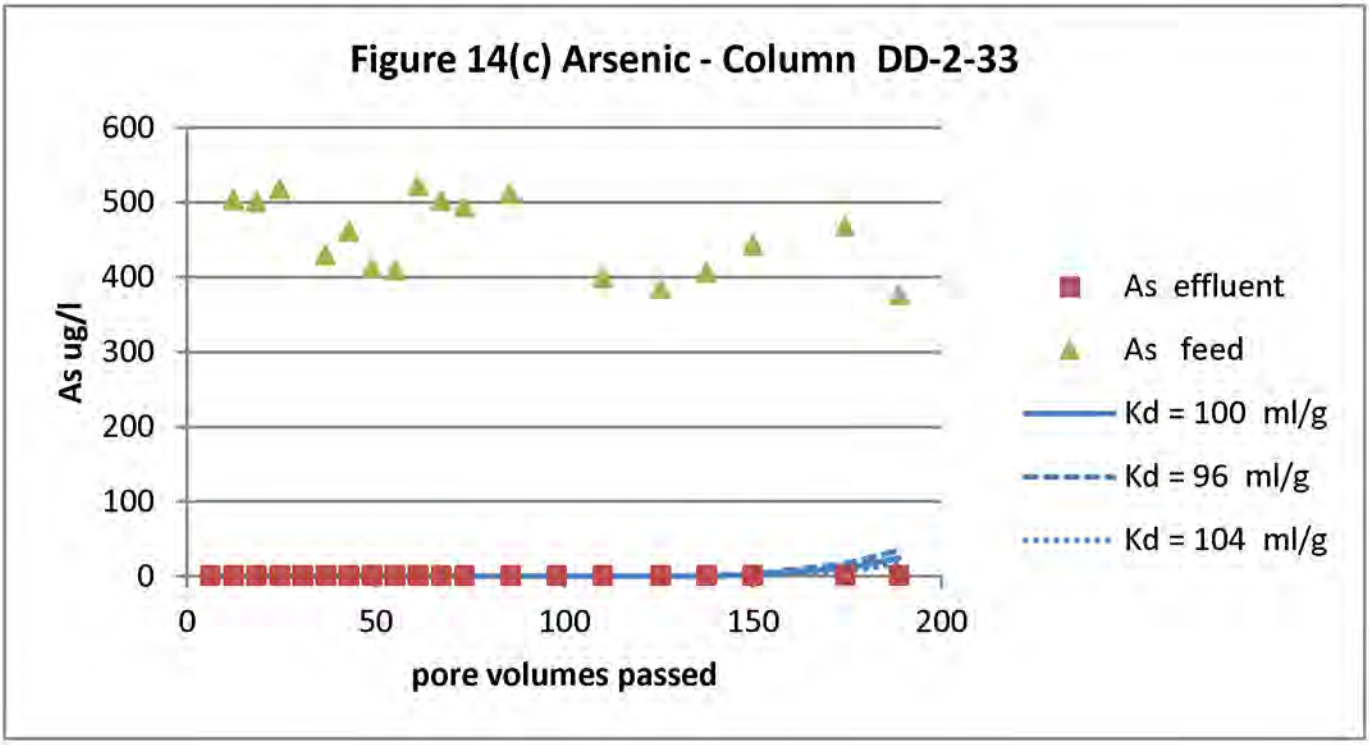


Figure 14(c) Arsenic - Column DD-2-33
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 100 ml/g
Kd = 96 ml/g
Kd = 104 ml/g

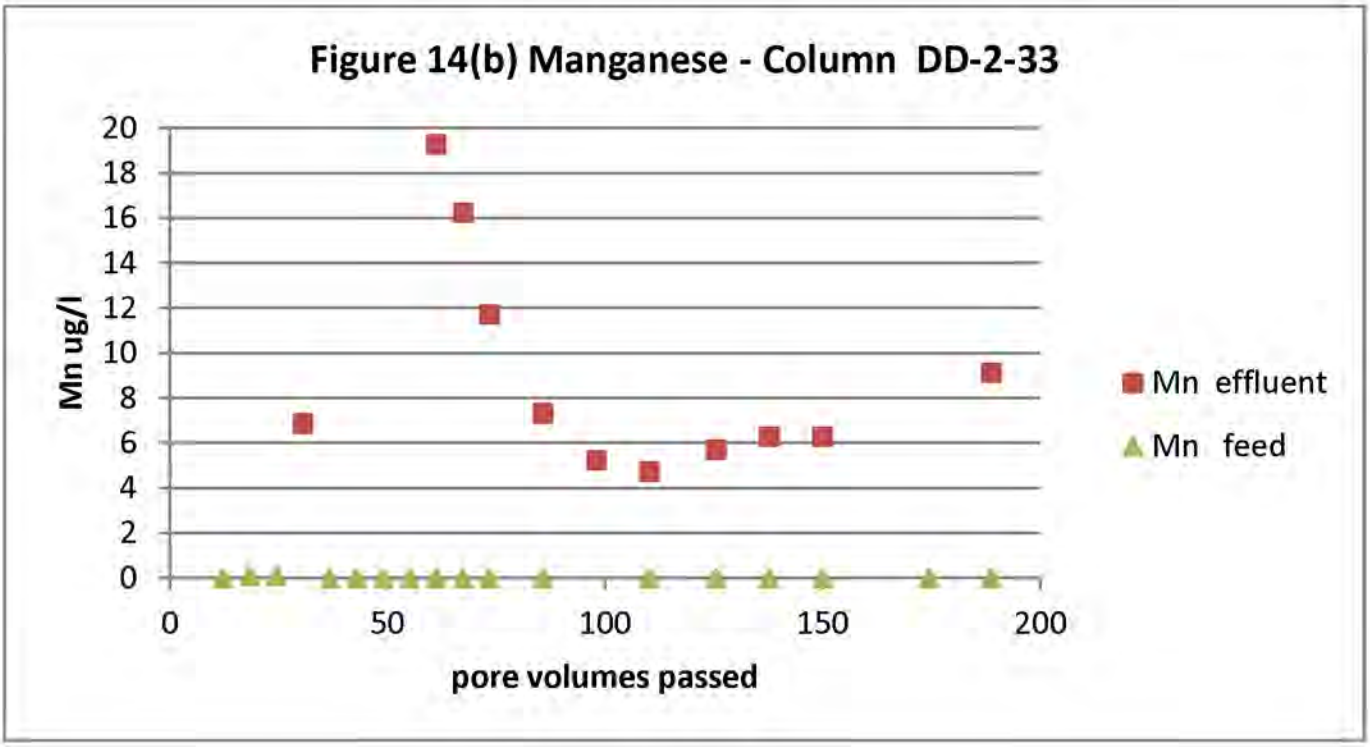


Figure 14(b) Manganese - Column DD-2-33
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

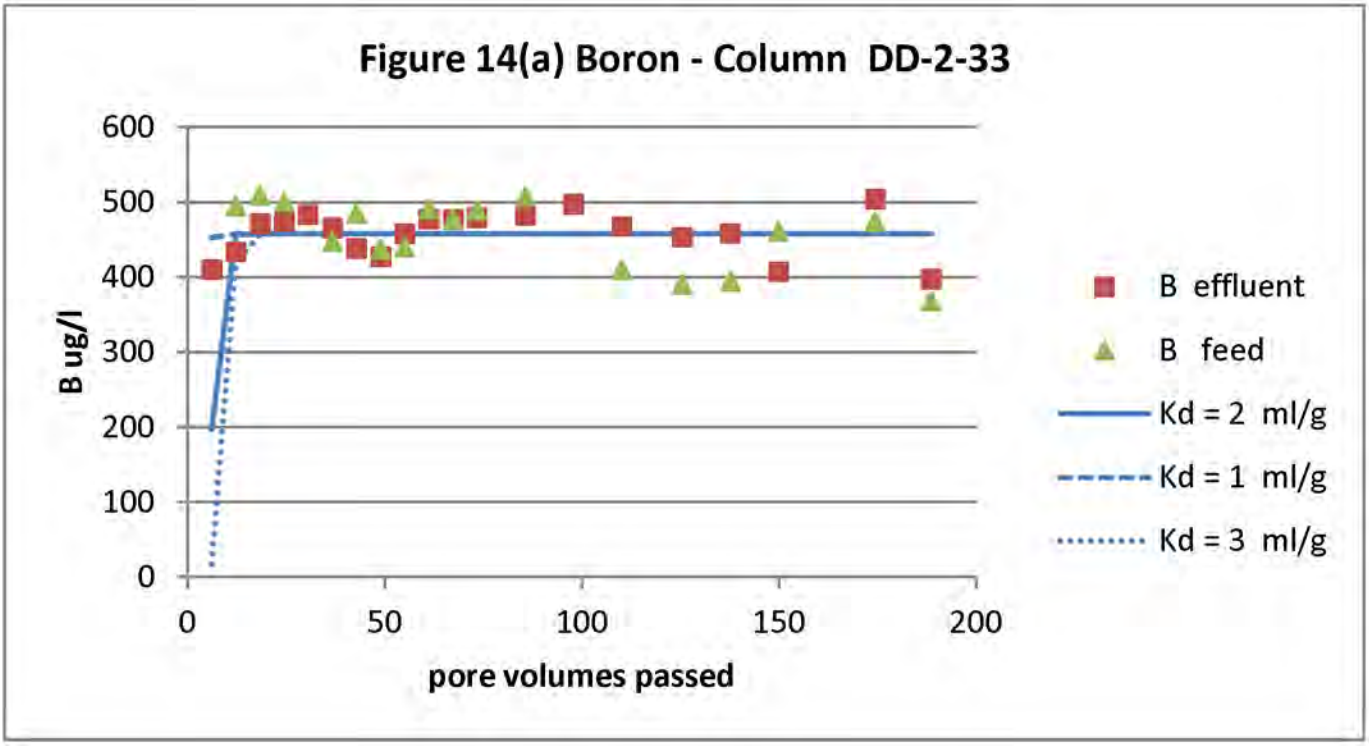


Figure 14(a) Boron - Column DD-2-33
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 2 ml/g
Kd = 1 ml/g
Kd = 3 ml/g

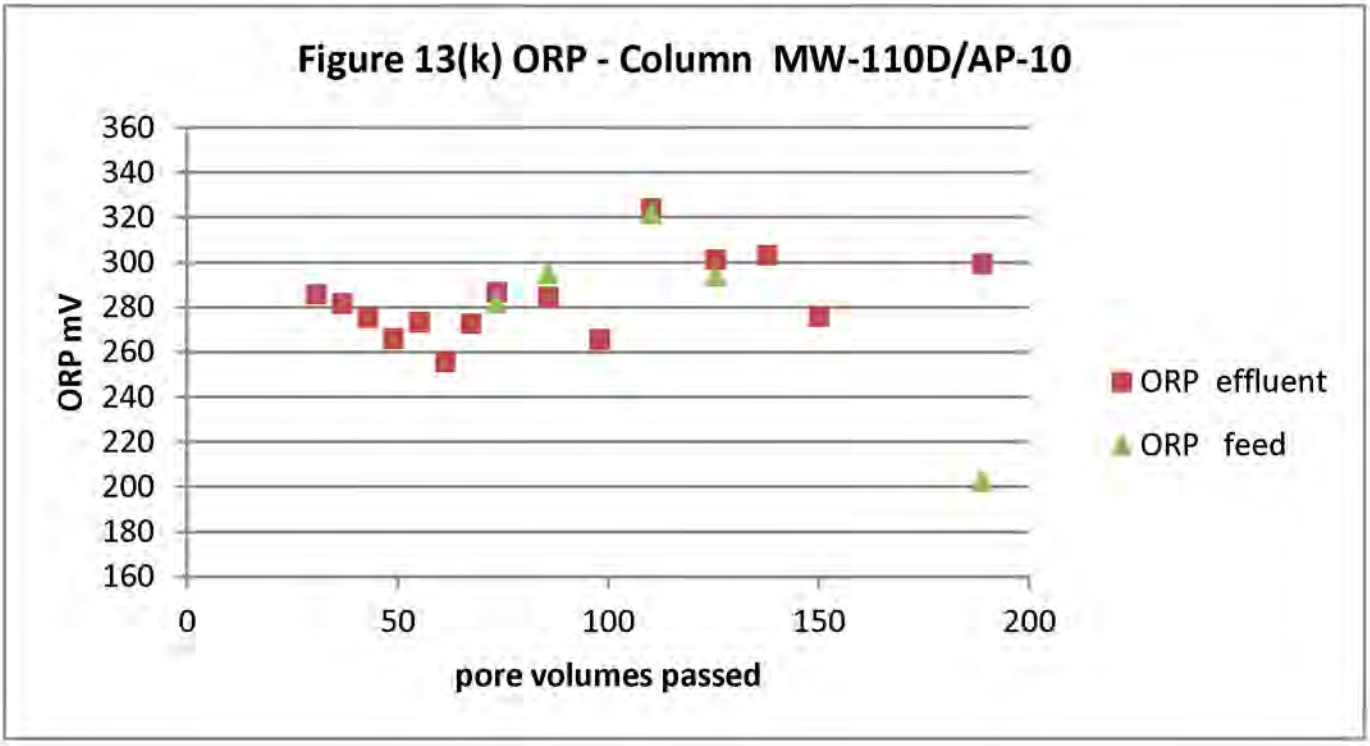


Figure 13(k) ORP - Column MW-110D/AP-10
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

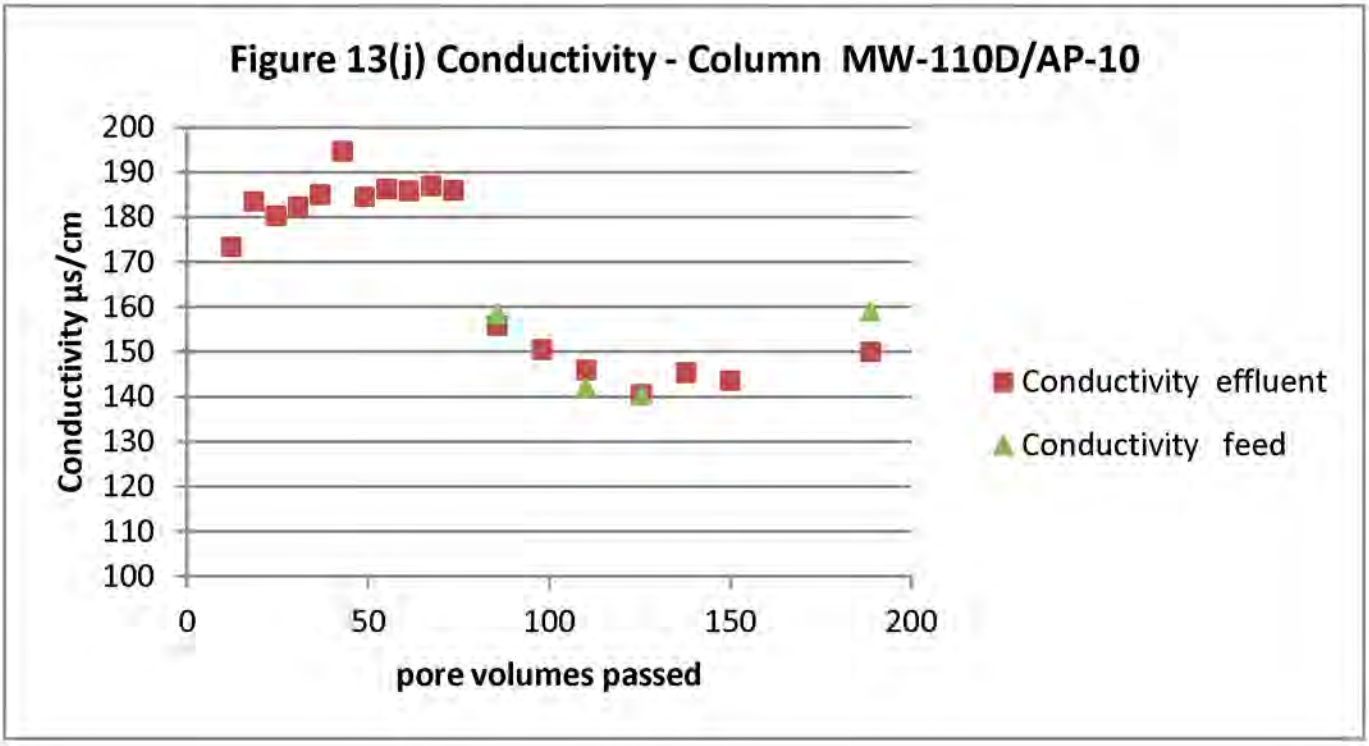


Figure 13(j) Conductivity - Column MW-110D/AP-10
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

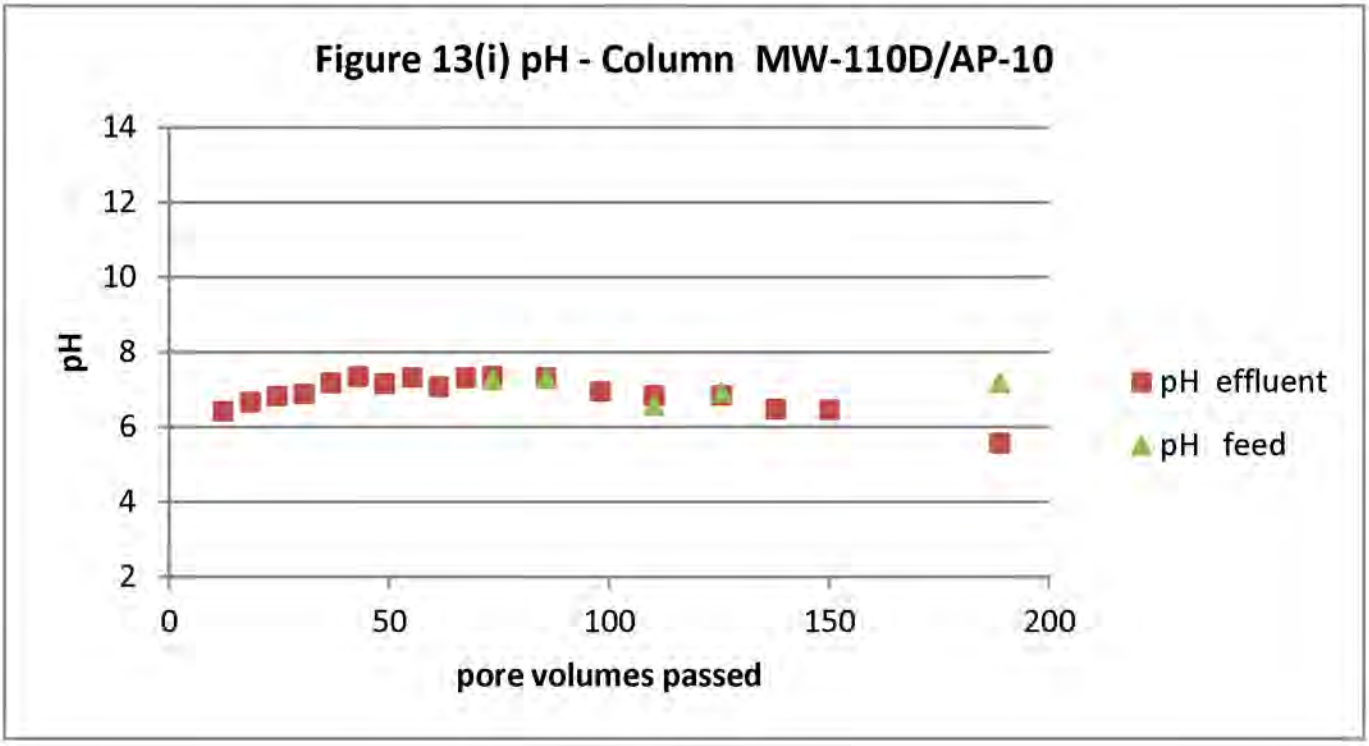


Figure 13(i) pH - Column MW-110D/AP-10
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

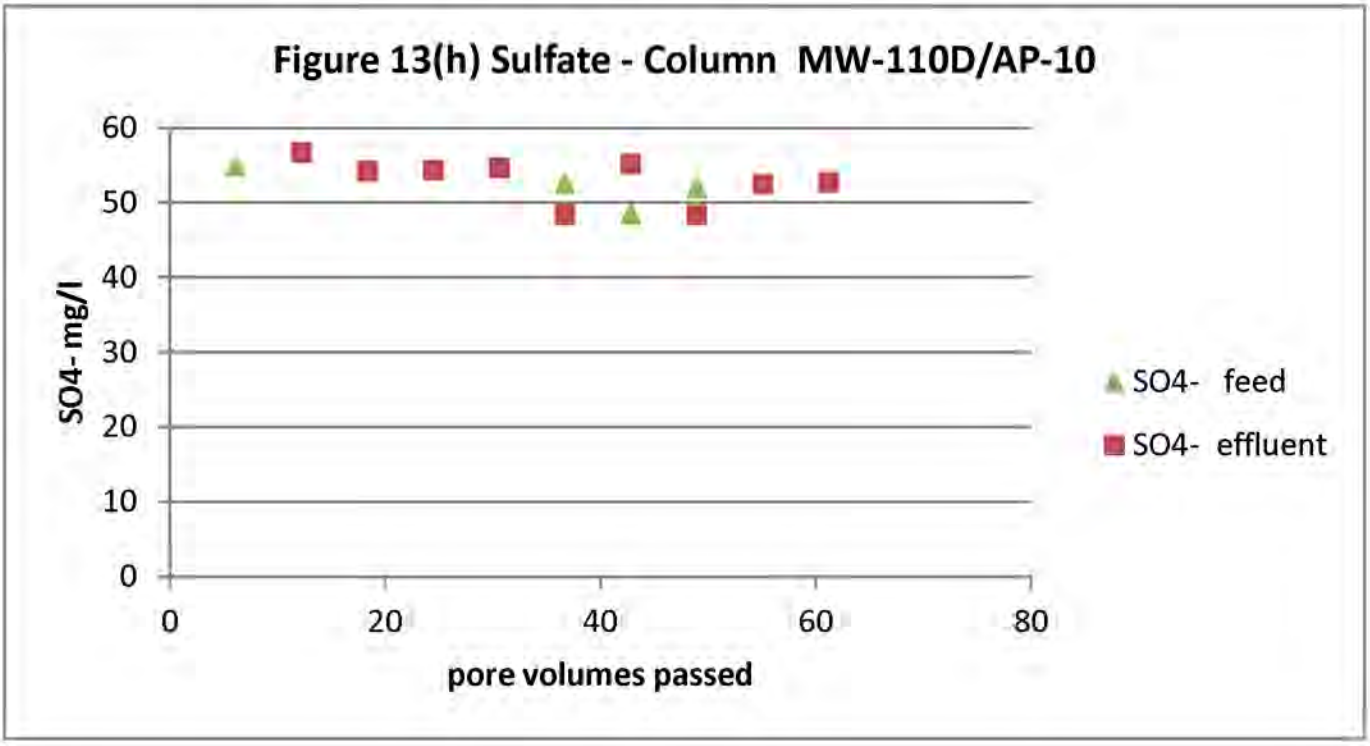


Figure 13(h) Sulfate - Column MW-110D/AP-10
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

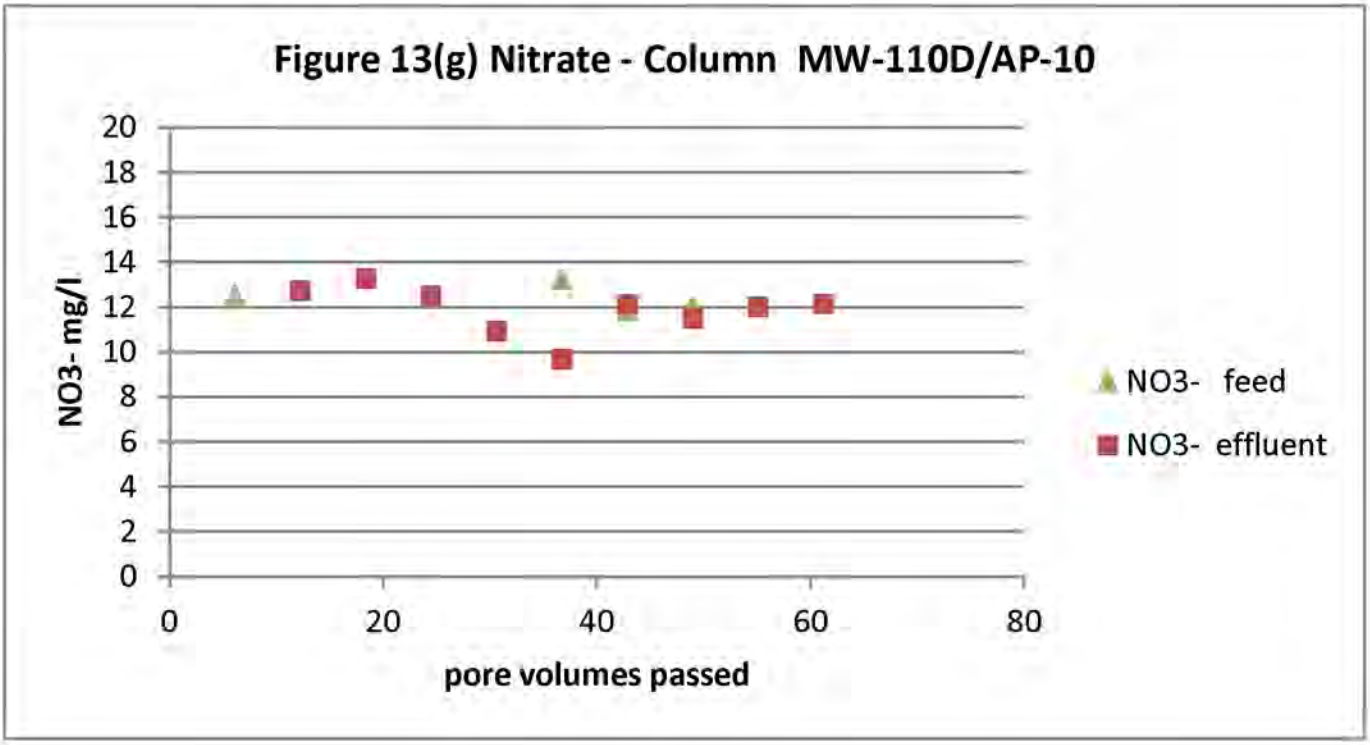


Figure 13(g) Nitrate - Column MW-110D/AP-10
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

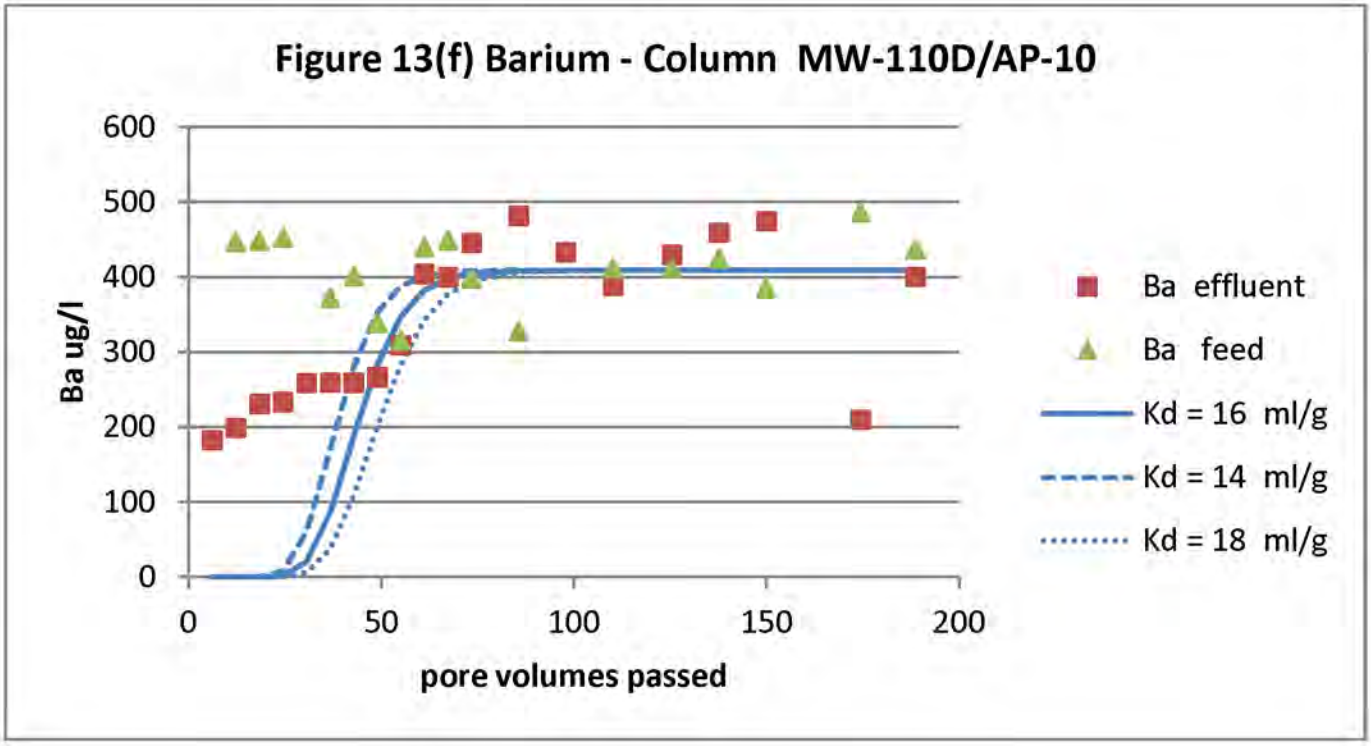


Figure 13(f) Barium - Column MW-110D/AP-10
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 16 ml/g
Kd = 14 ml/g
Kd = 18 ml/g

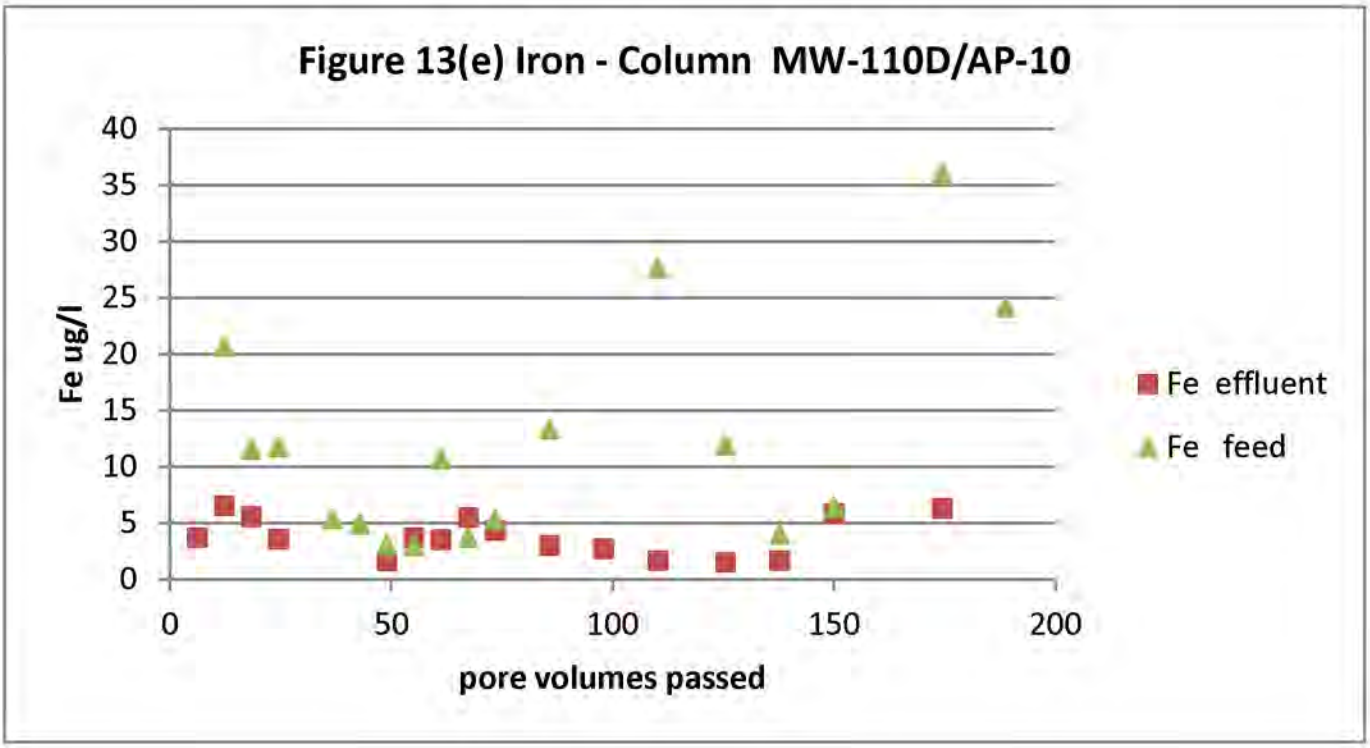


Figure 13(e) Iron - Column MW-110D/AP-10
Fe ug/l
40
35
30
25
20
15
10
5
0
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

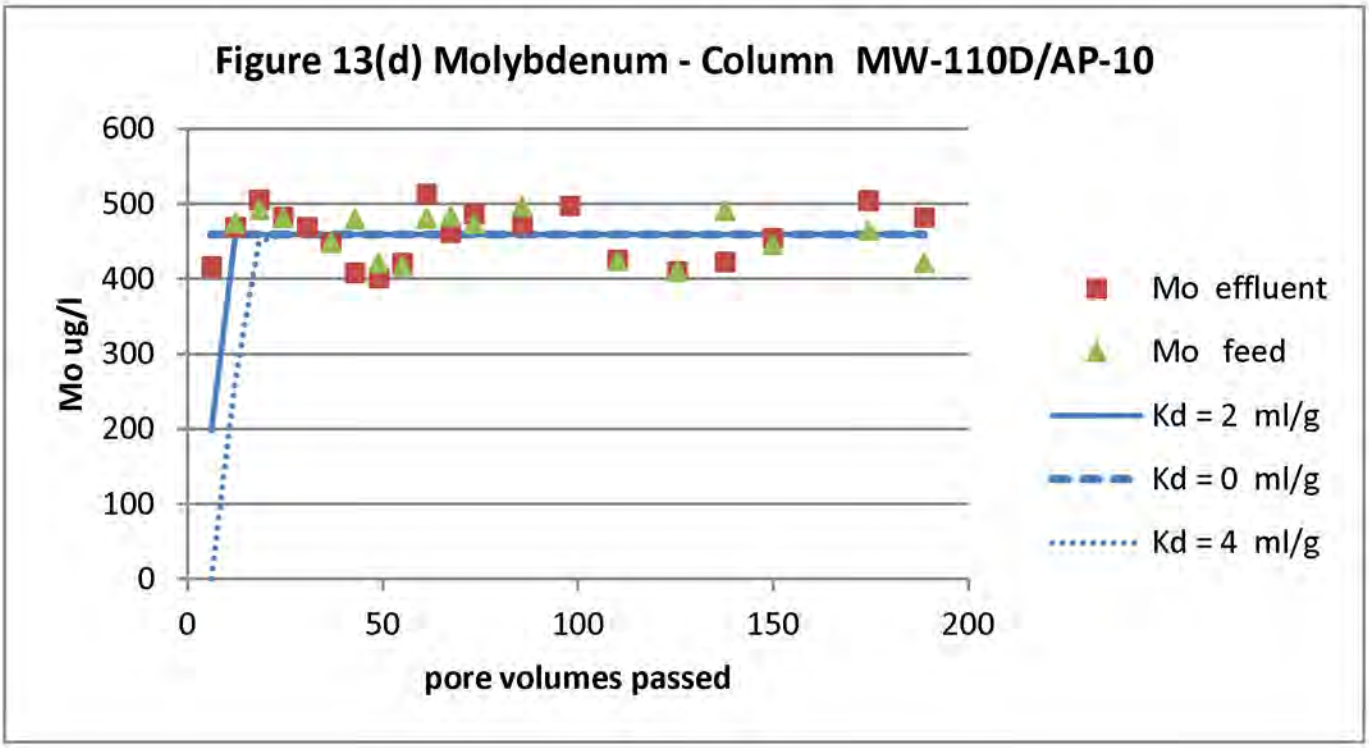


Figure 13(d) Molybdenum - Column MW-110D/AP-10
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 2 ml/g
Kd = 0 ml/g
Kd = 4 ml/g

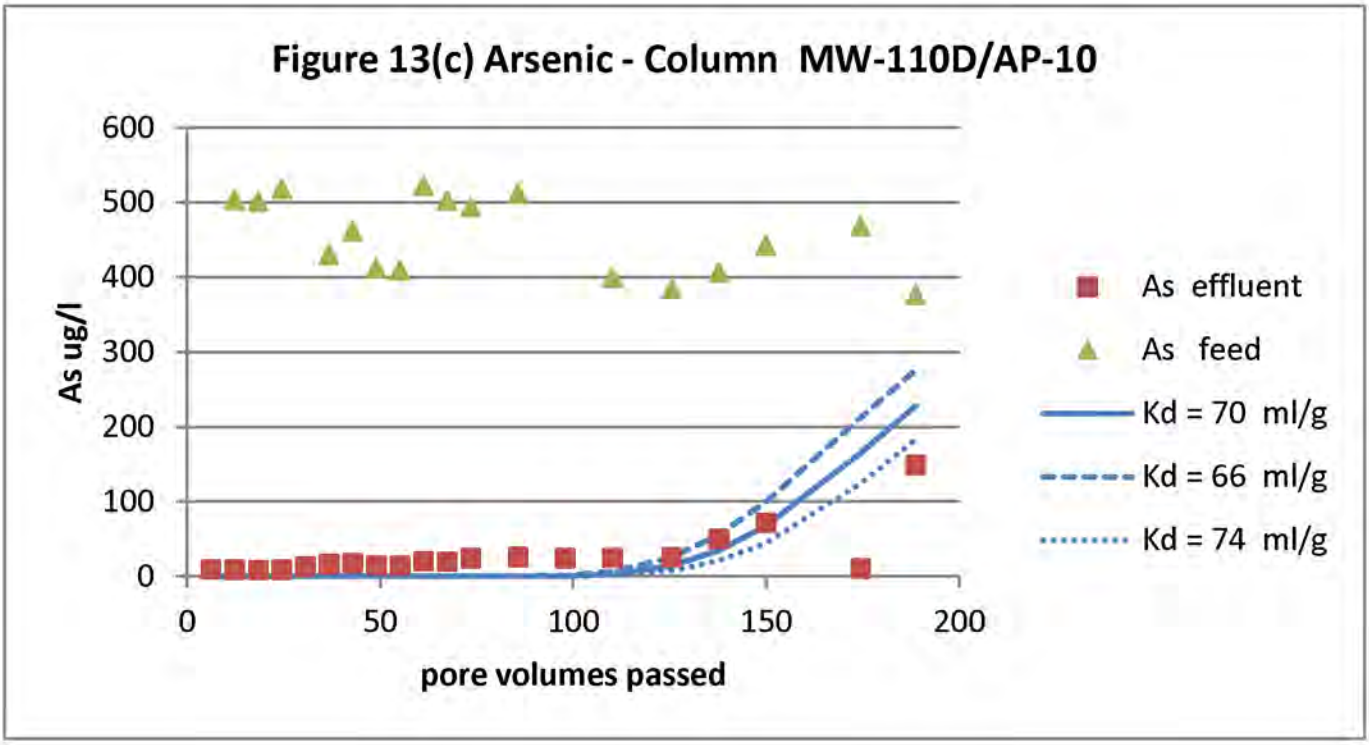


Figure 13(c) Arsenic - Column MW-110D/AP-10
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 70 ml/g
Kd = 66 ml/g
Kd = 74 ml/g

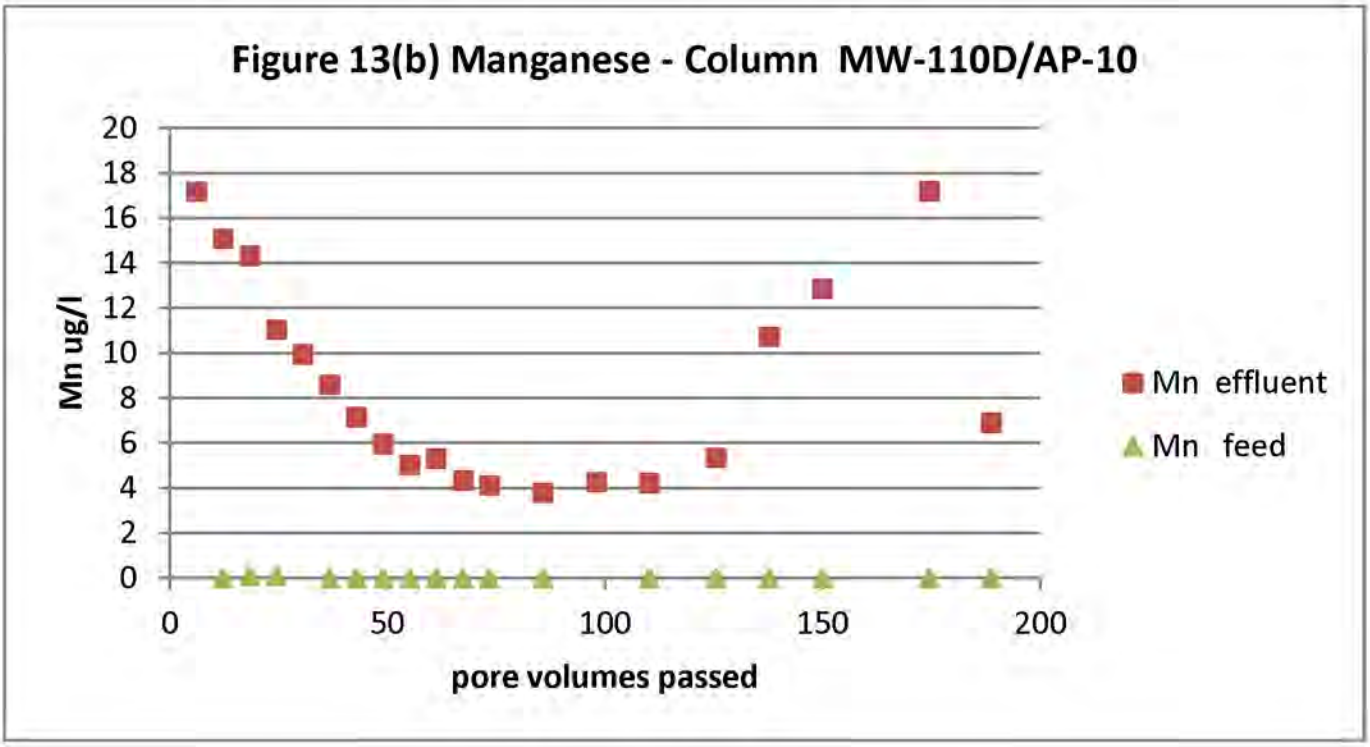


Figure 13(b) Manganese - Column MW-110D/AP-10
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

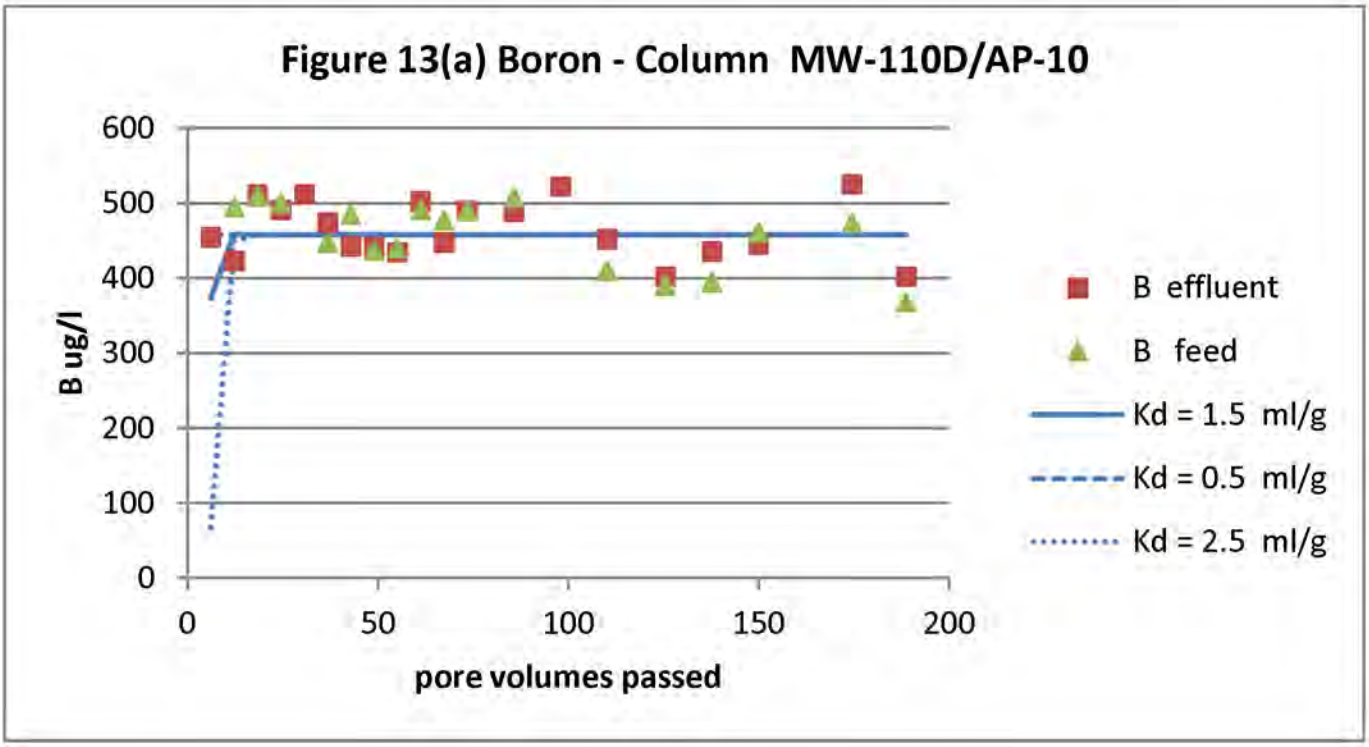


Figure 13(a) Boron - Column MW-110D/AP-10
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 1.5 ml/g
Kd = 0.5 ml/g
Kd = 2.5 ml/g

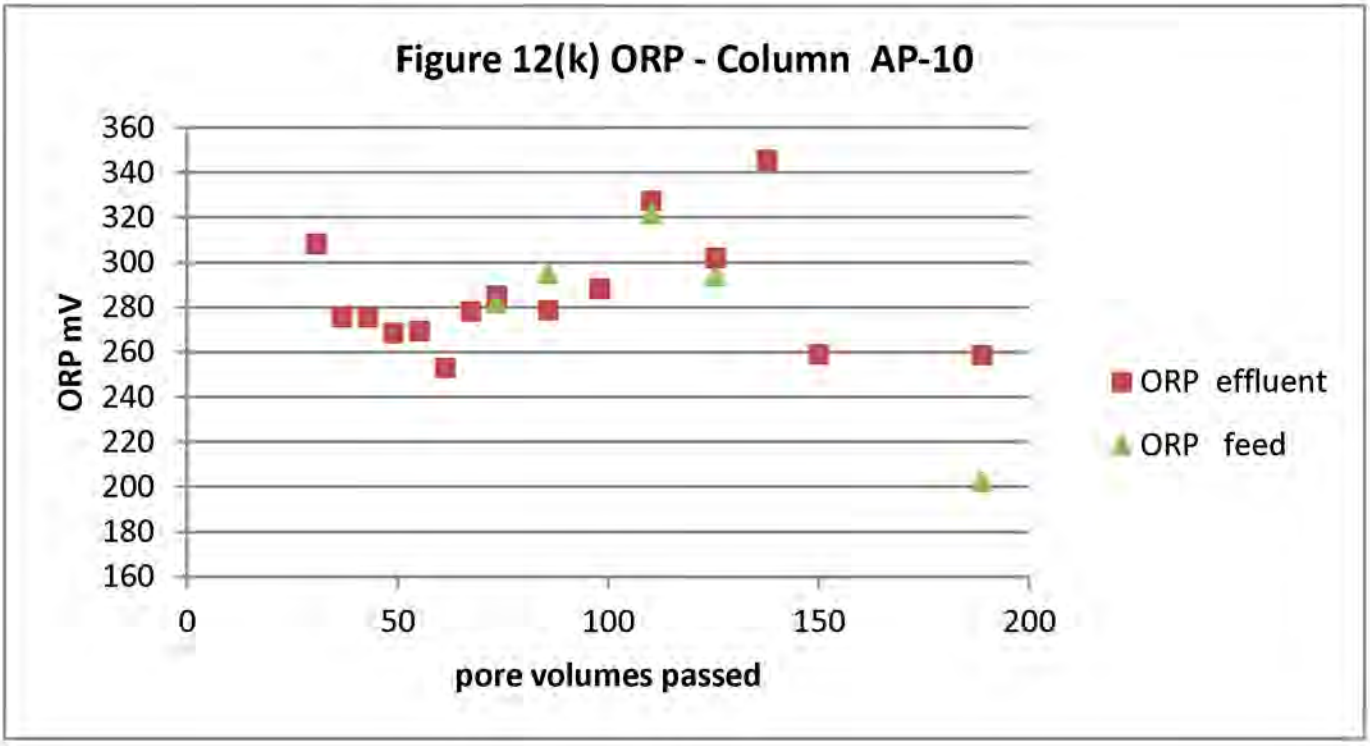


Figure 12(k) ORP - Column AP-10
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

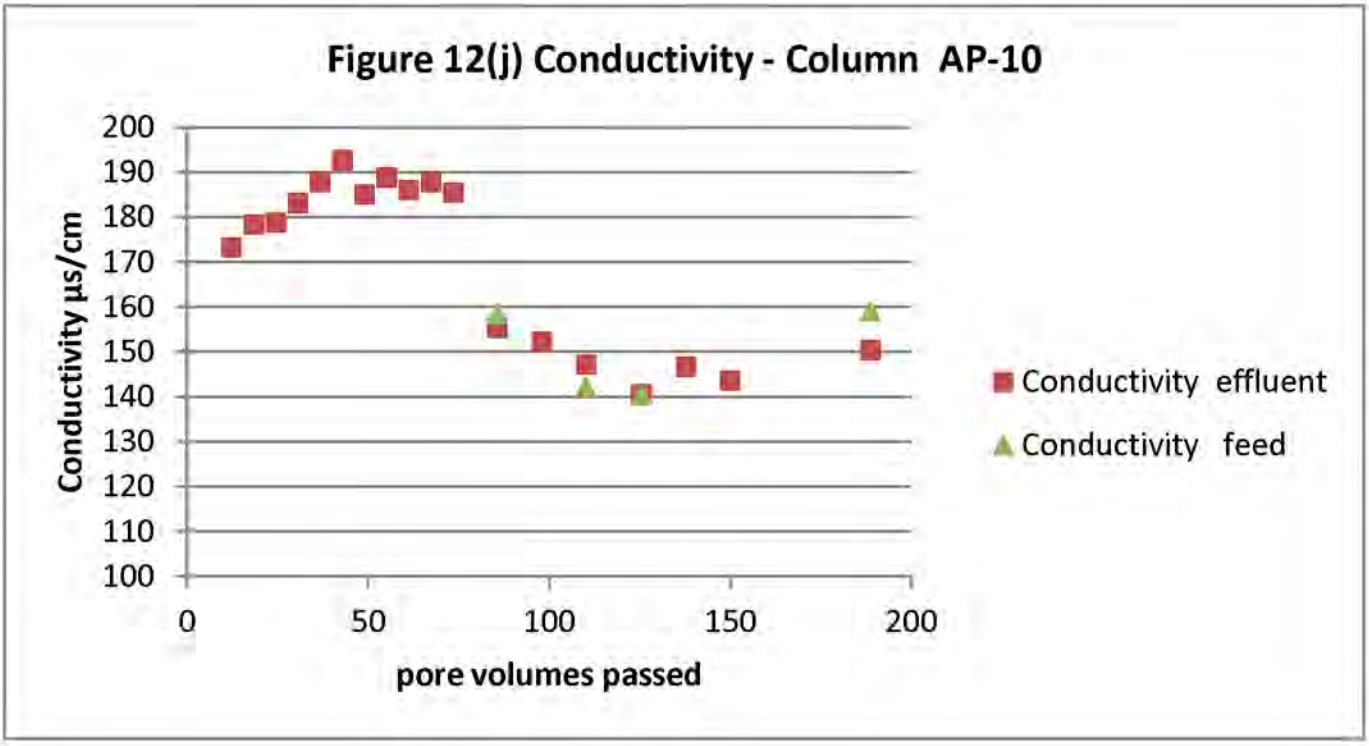


Figure 12(j) Conductivity - Column AP-10
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

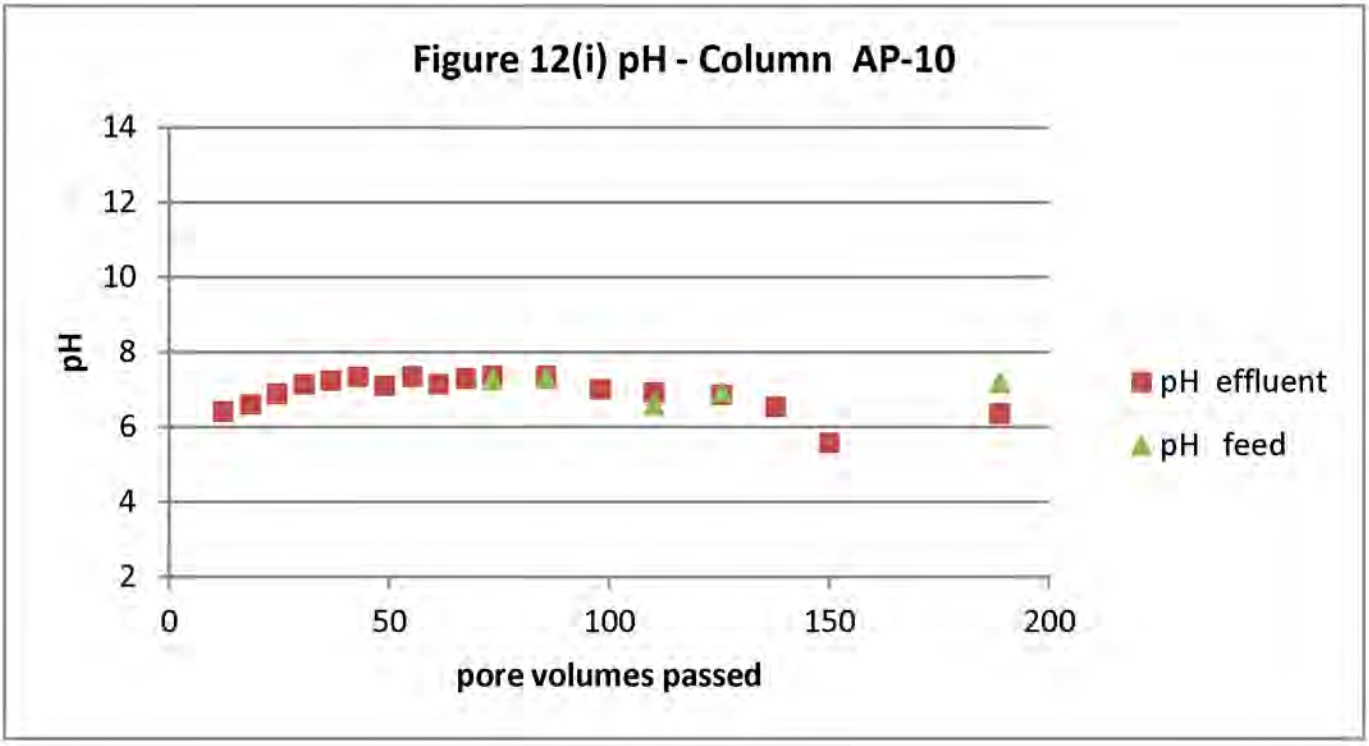


Figure 12(i) pH - Column AP-10
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

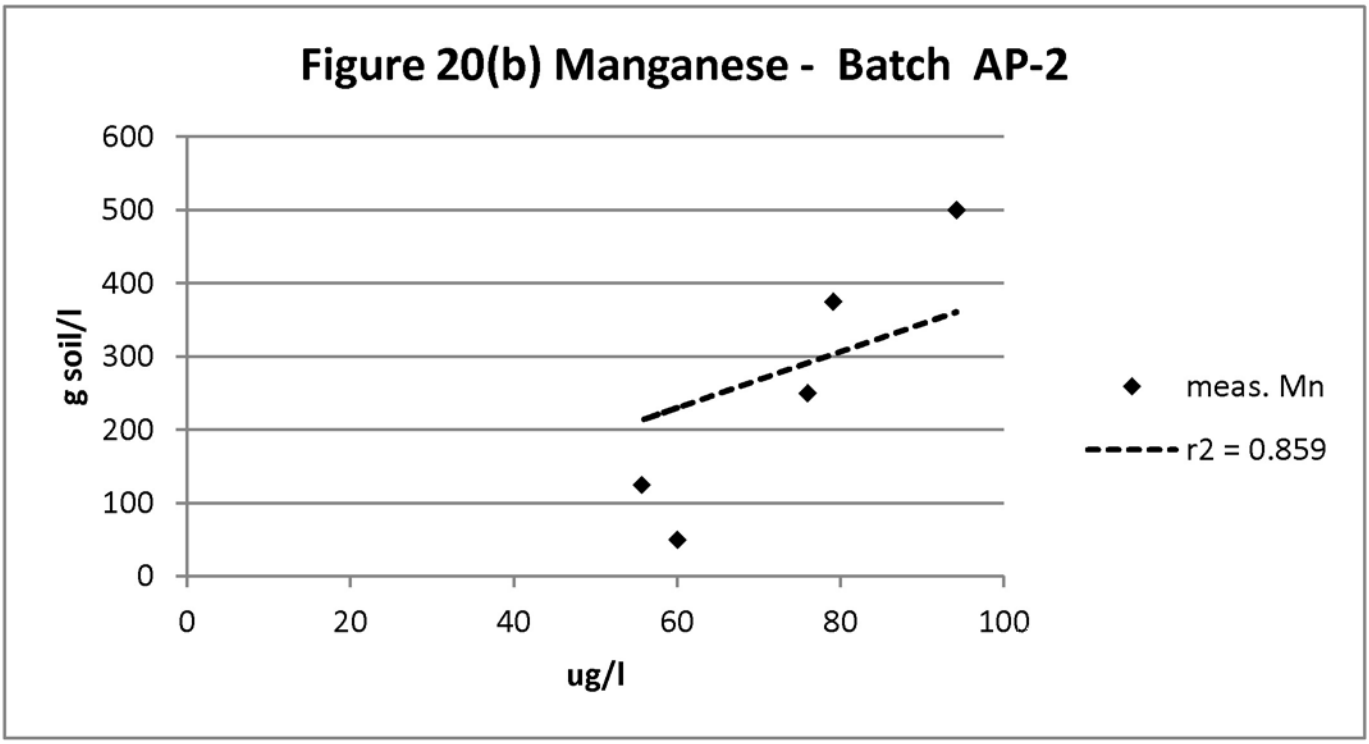


Figure 20(b) Manganese - Batch AP-2
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
100
ug/l
meas. Mn
r2 = 0.859

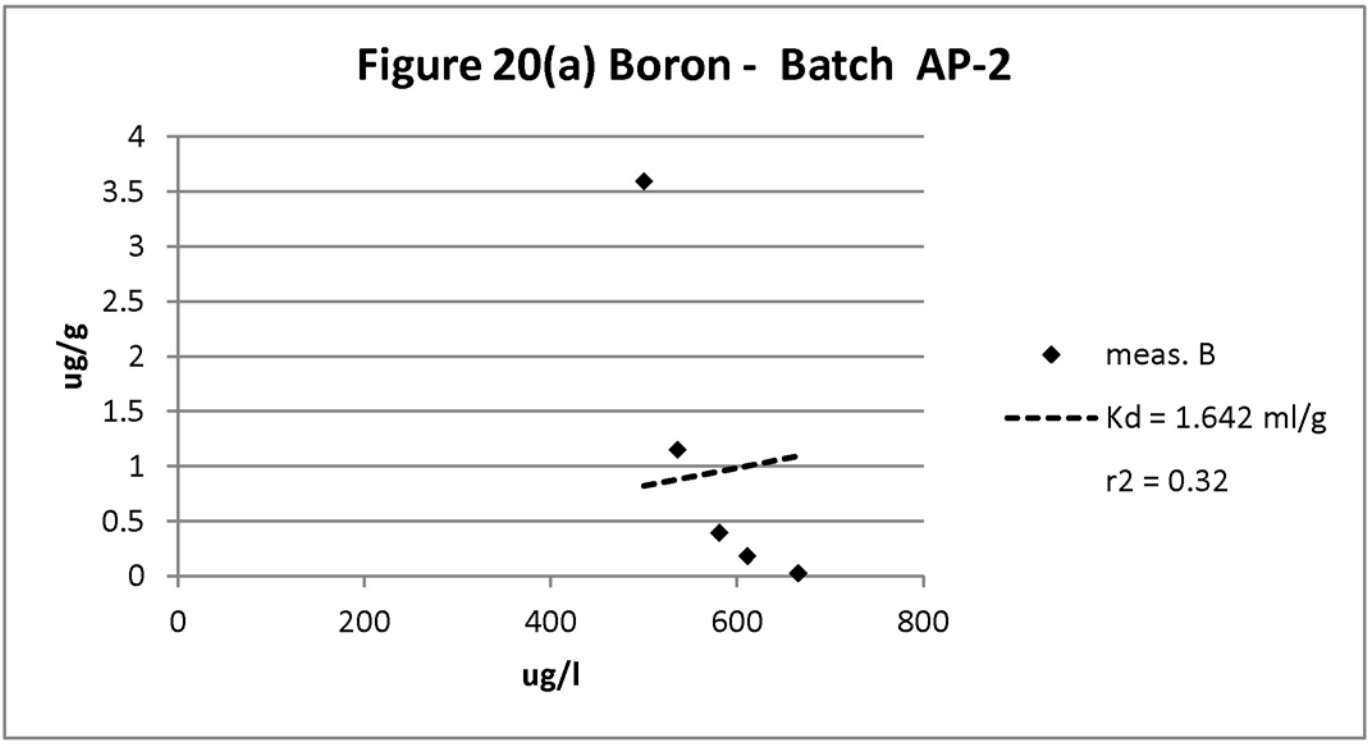


Figure 20(a) Boron - Batch AP-2
4
3.5
3
2.5
2
1.5
1
0.5
0
ug/g
0
200
400
600
800
ug/l
meas. B
Kd = 1.642 ml/g
r2 = 0.32

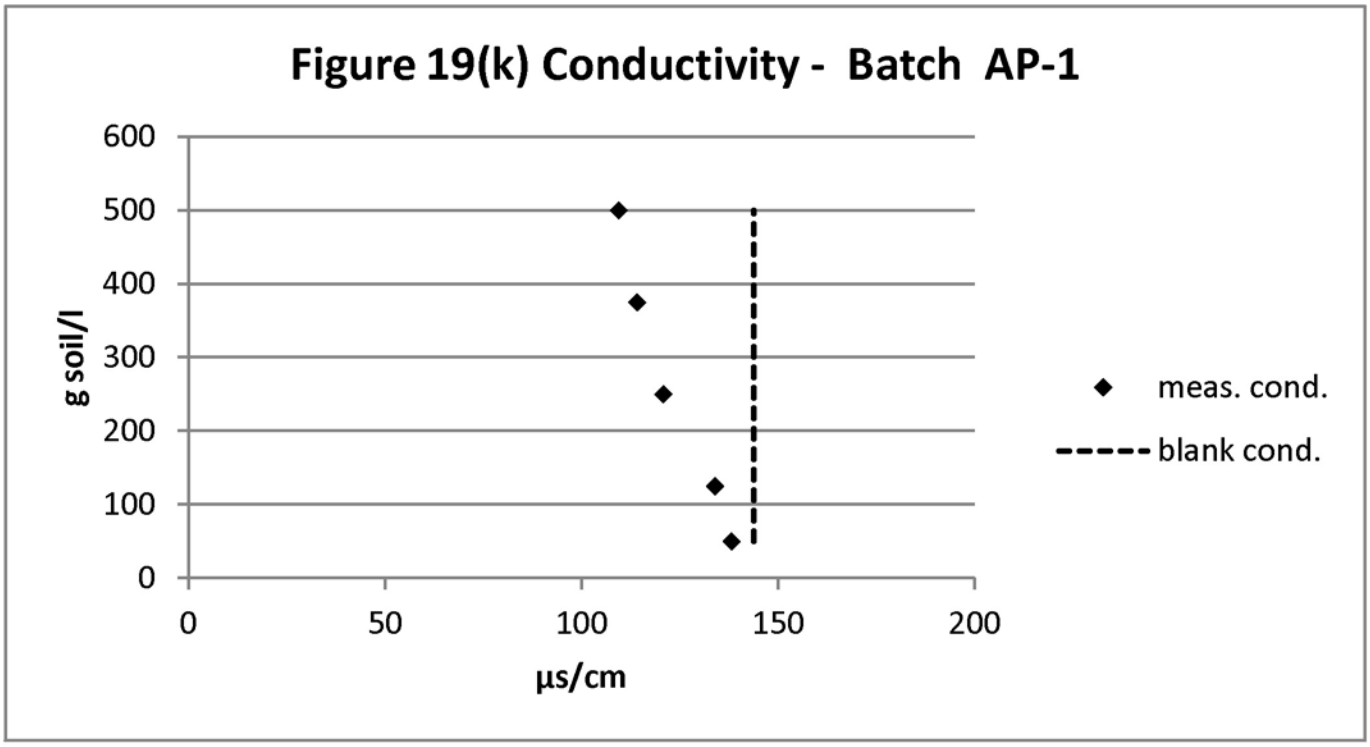


Figure 19(k) Conductivity - Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
µs/cm
meas. cond.
blank cond.

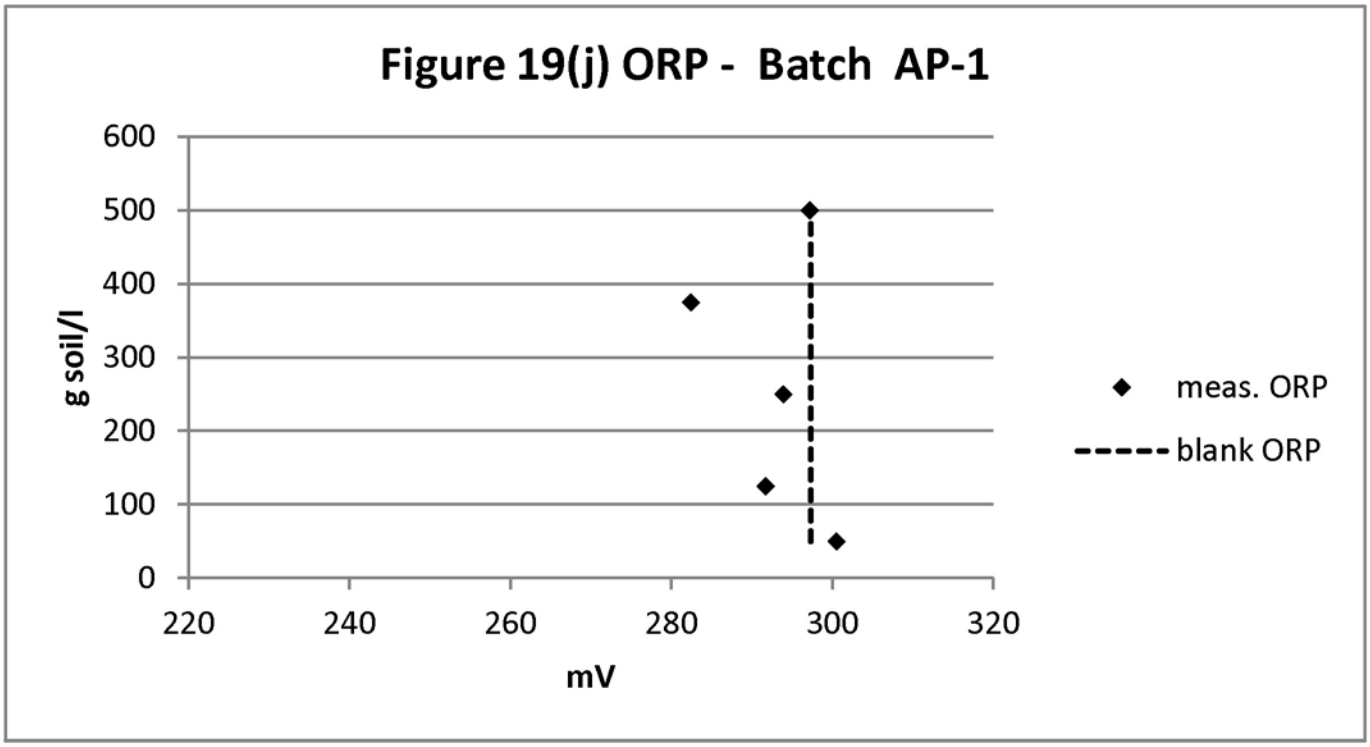


Figure 19(j) ORP - Batch AP-1
600
500
400
300
200
100
0
g soil/l
220
240
260
280
300
320
mV
meas. ORP
blank ORP

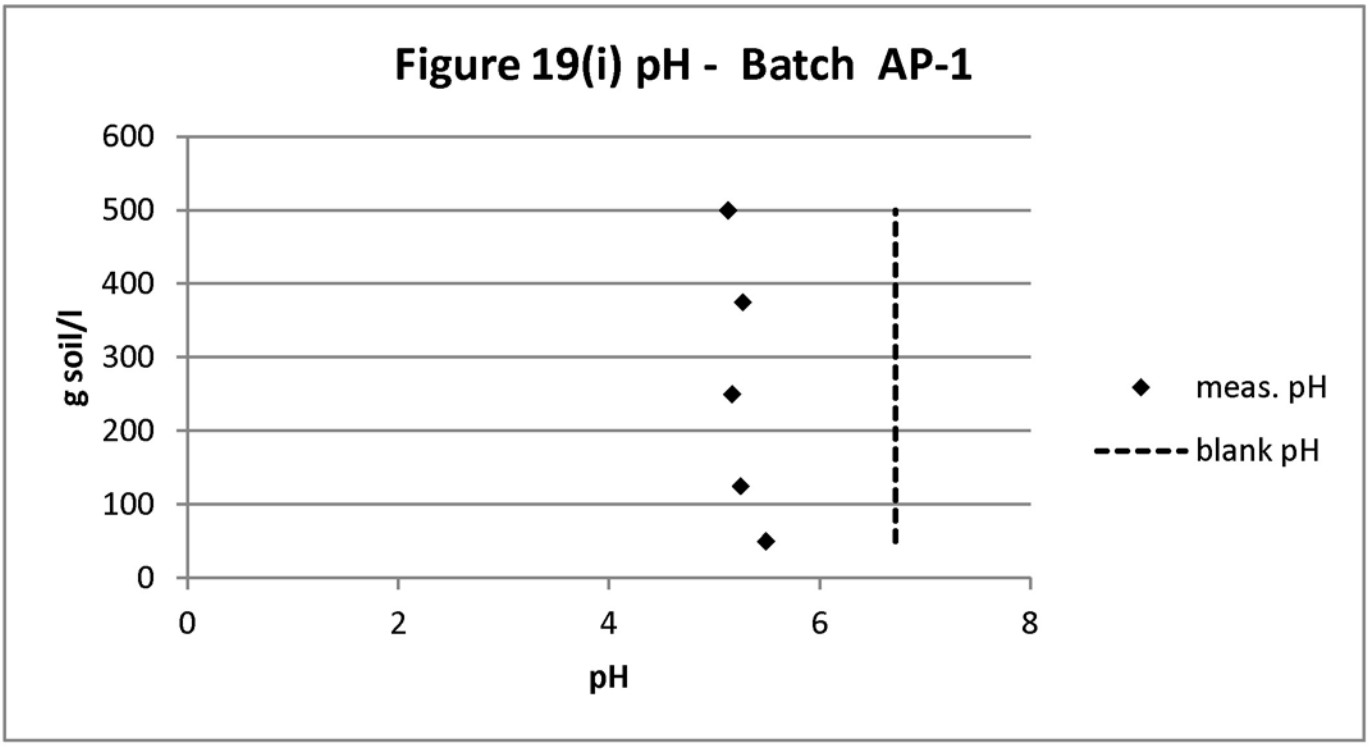


Figure 19(i) pH - Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
2
4
6
8
pH
meas. pH
blank pH

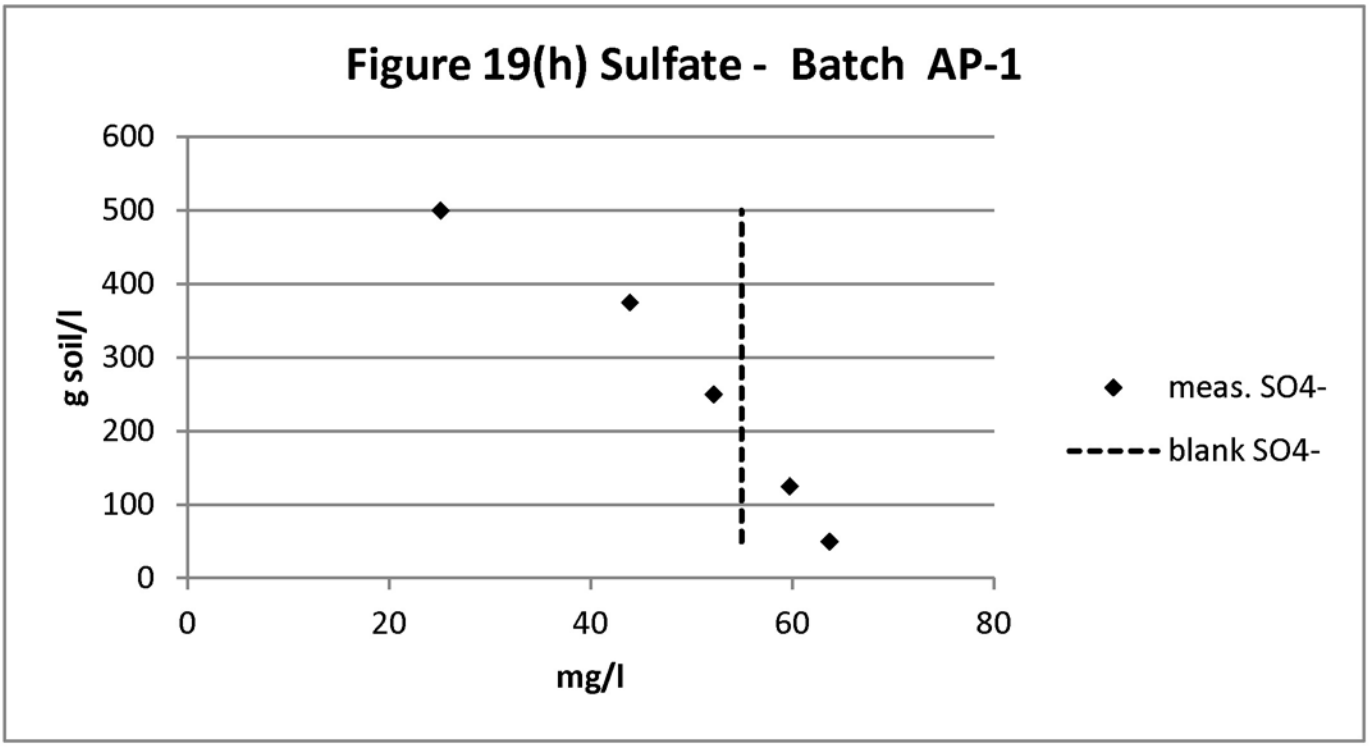


Figure 19(h) Sulfate - Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

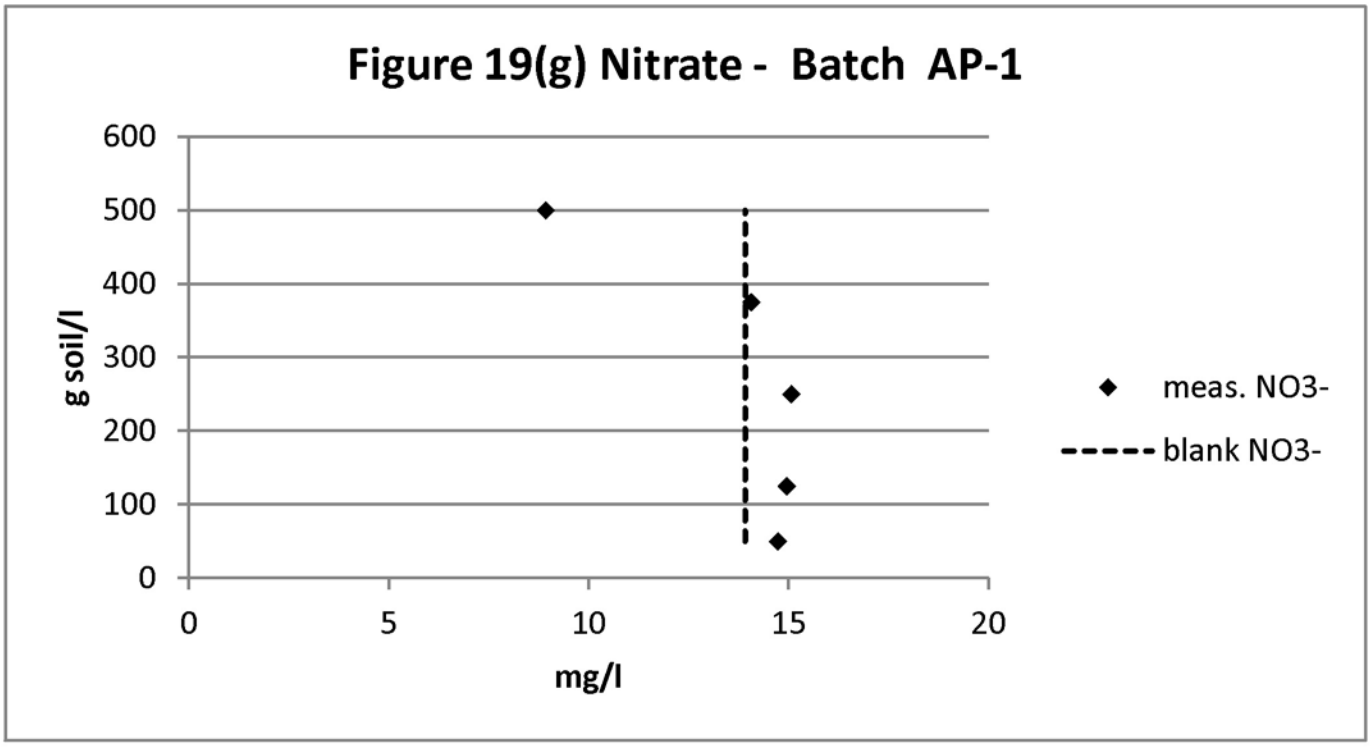


Figure 19(g) Nitrate - Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

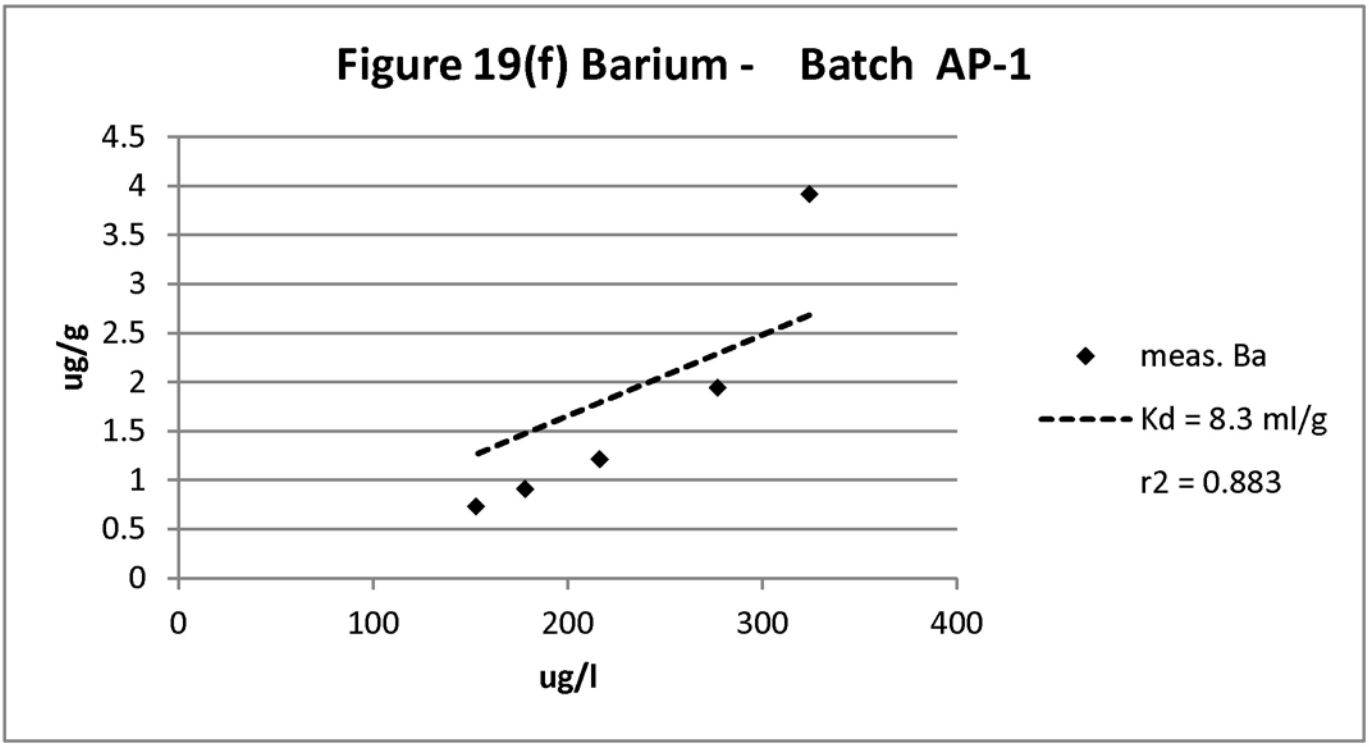


Figure 19(f) Barium - Batch AP-1
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
ug/g
0
100
200
300
400
ug/l
meas. Ba
Kd = 8.3 ml/g
r2 = 0.883

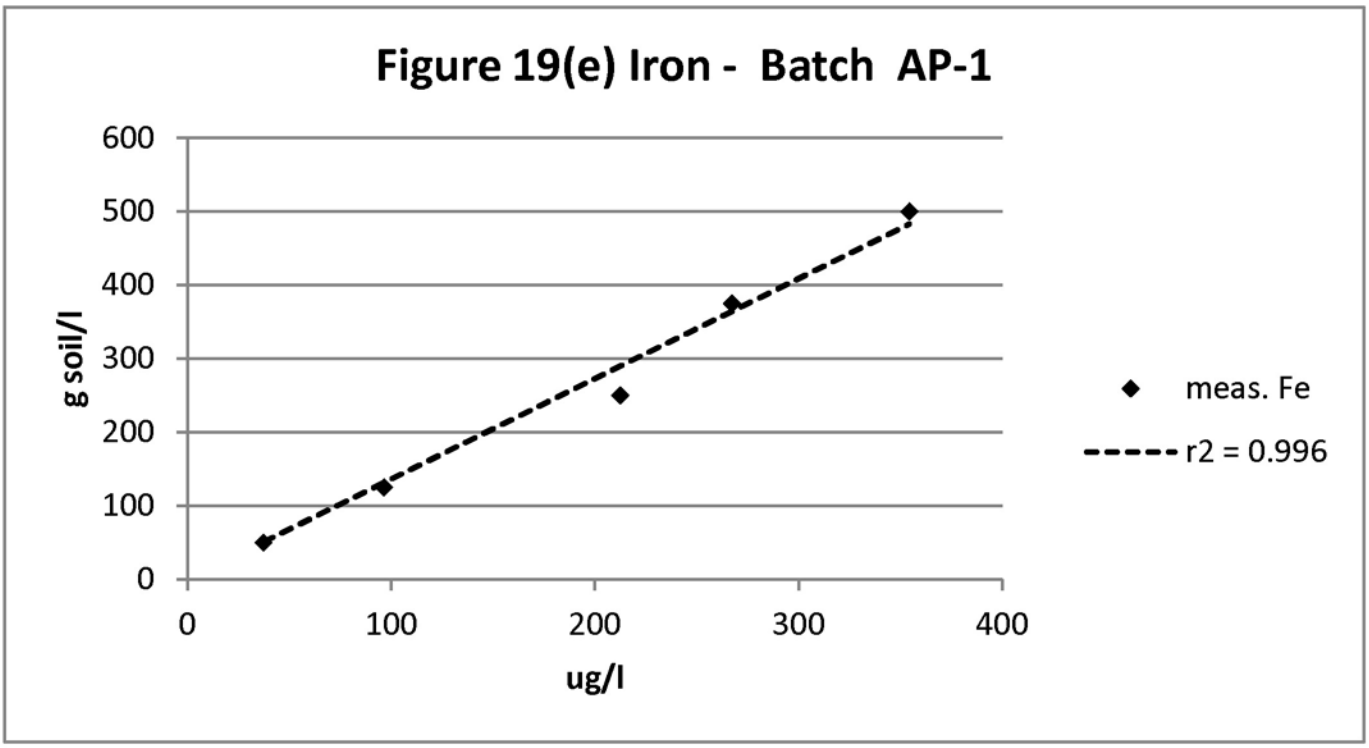


Figure 19(e) Iron - Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
100
200
300
400
ug/l
meas. Fe
r2 = 0.996

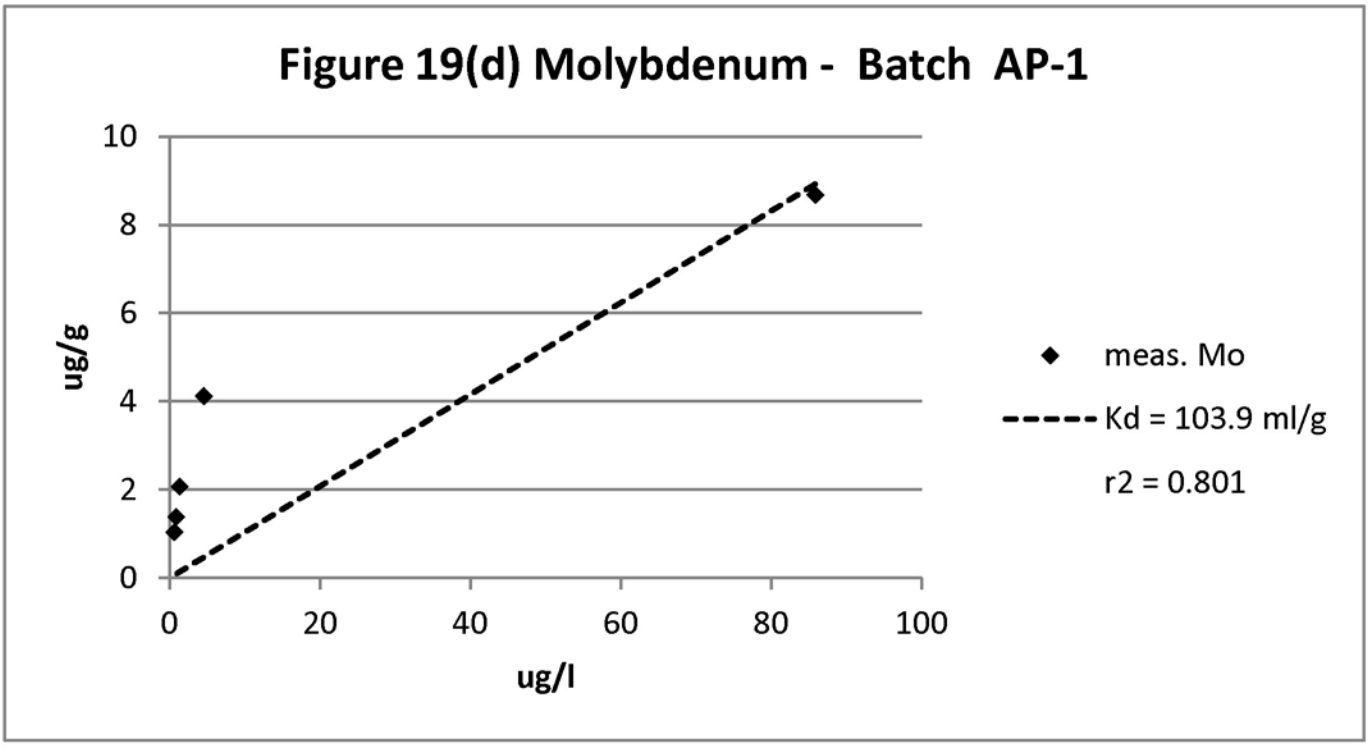


Figure 19(d) Molybdenum - Batch AP-1
10
8
6
4
2
0
ug/g
0
20
40
60
80
100
ug/l
meas. Mo
Kd = 103.9 ml/g
r2 = 0.801

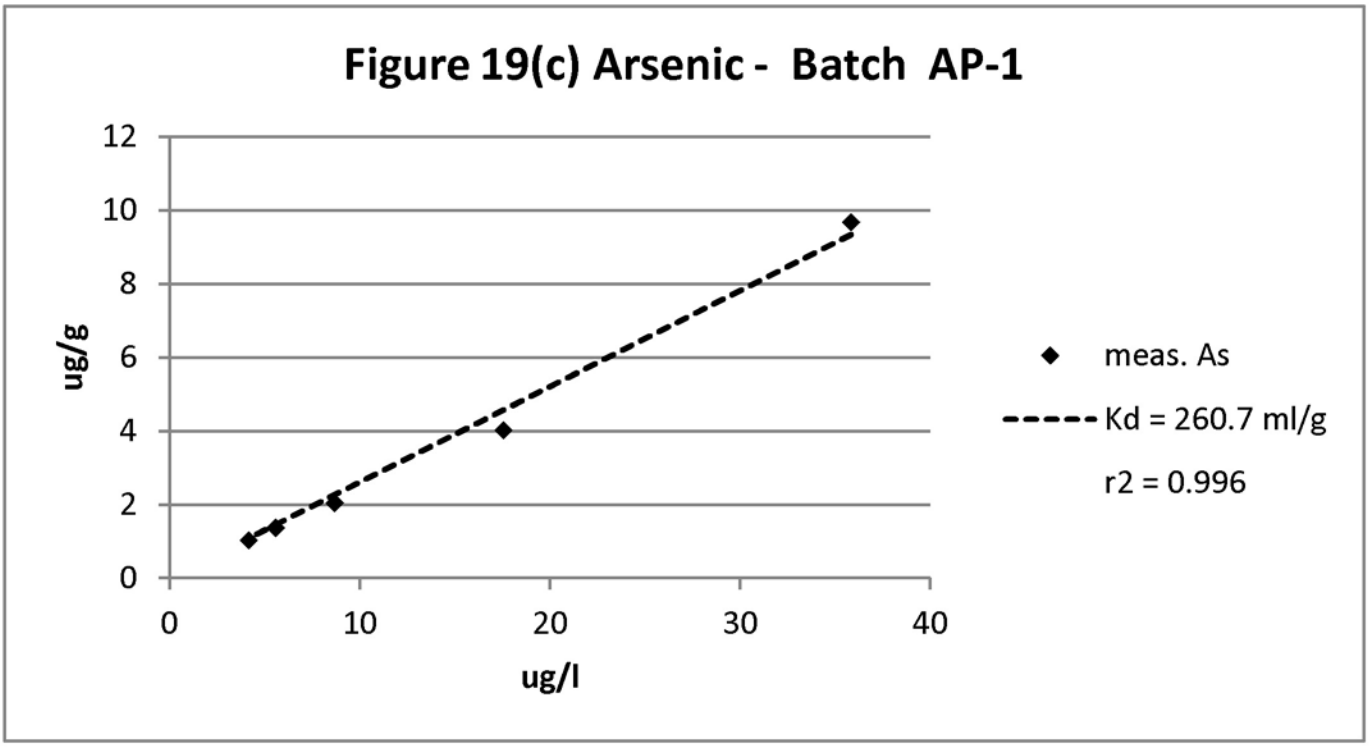


Figure 19(c) Arsenic - Batch AP-1
12
10
8
6
4
2
0
ug/g
0
10
20
30
40
ug/l
meas. As
Kd = 260.7 ml/g
r2 = 0.996

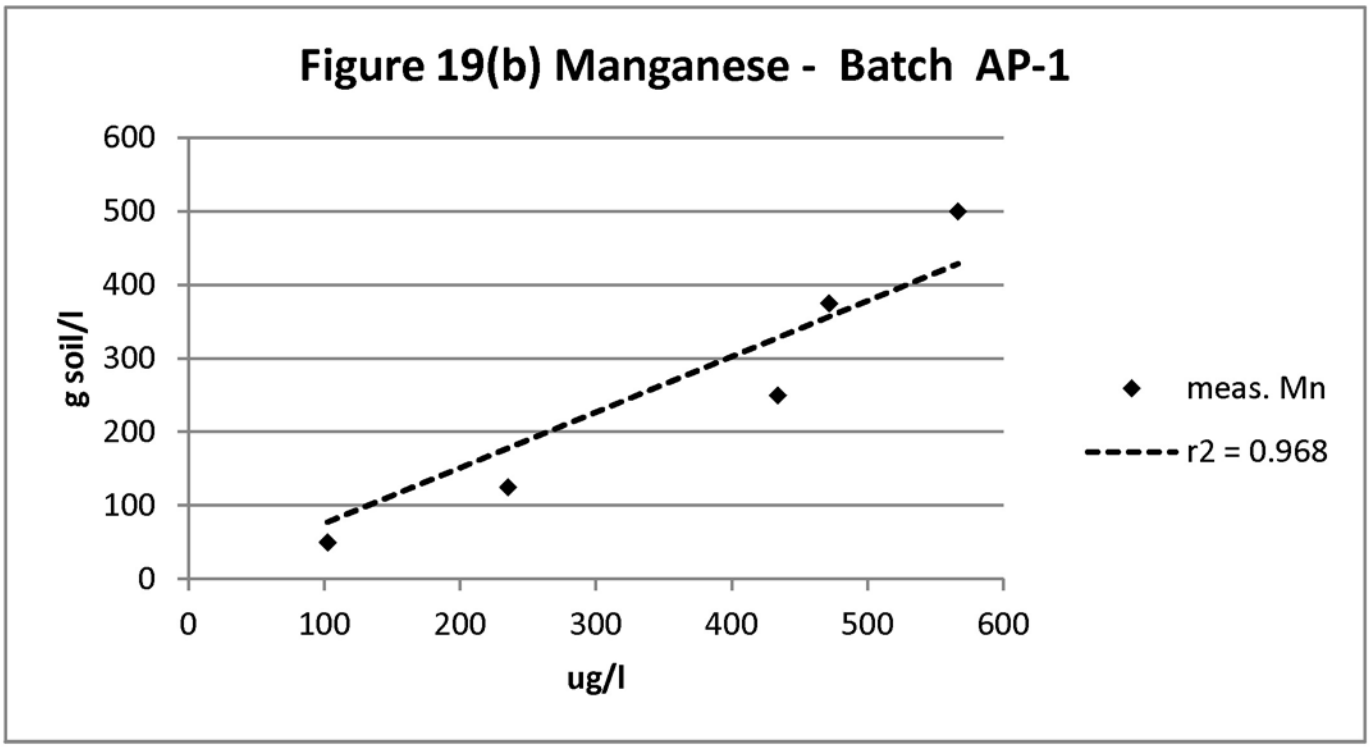


Figure 19(b) Manganese - Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
100
200
300
400
500
600
ug/l
meas. Mn
r2 = 0.968

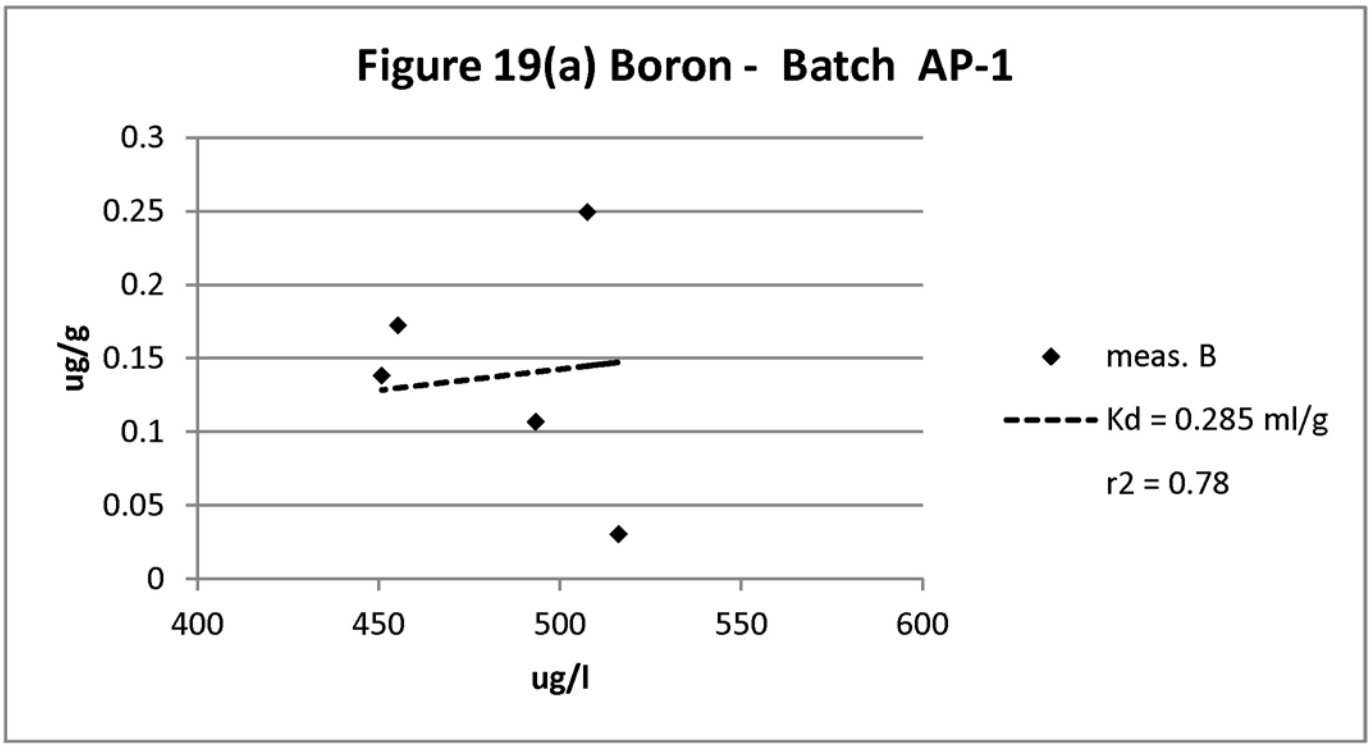


Figure 19(a) Boron - Batch AP-1
0.3
0.25
0.2
0.15
0.1
0.05
0
ug/g
400
450
500
550
600
ug/l
meas. B
Kd = 0.285 ml/g
r2 = 0.78

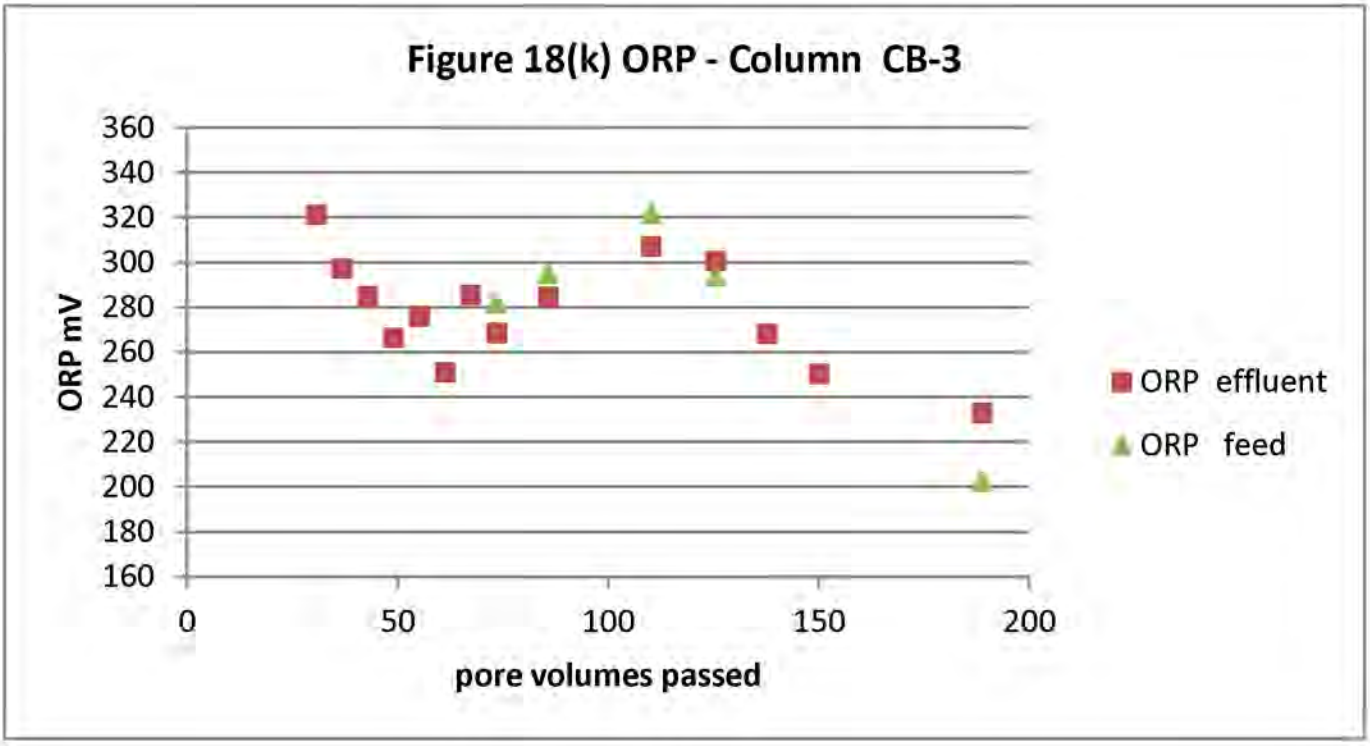


Figure 18(k) ORP - Column CB-3
ORP mV
360
340
320
300
280
260
240
220
200
180
160
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

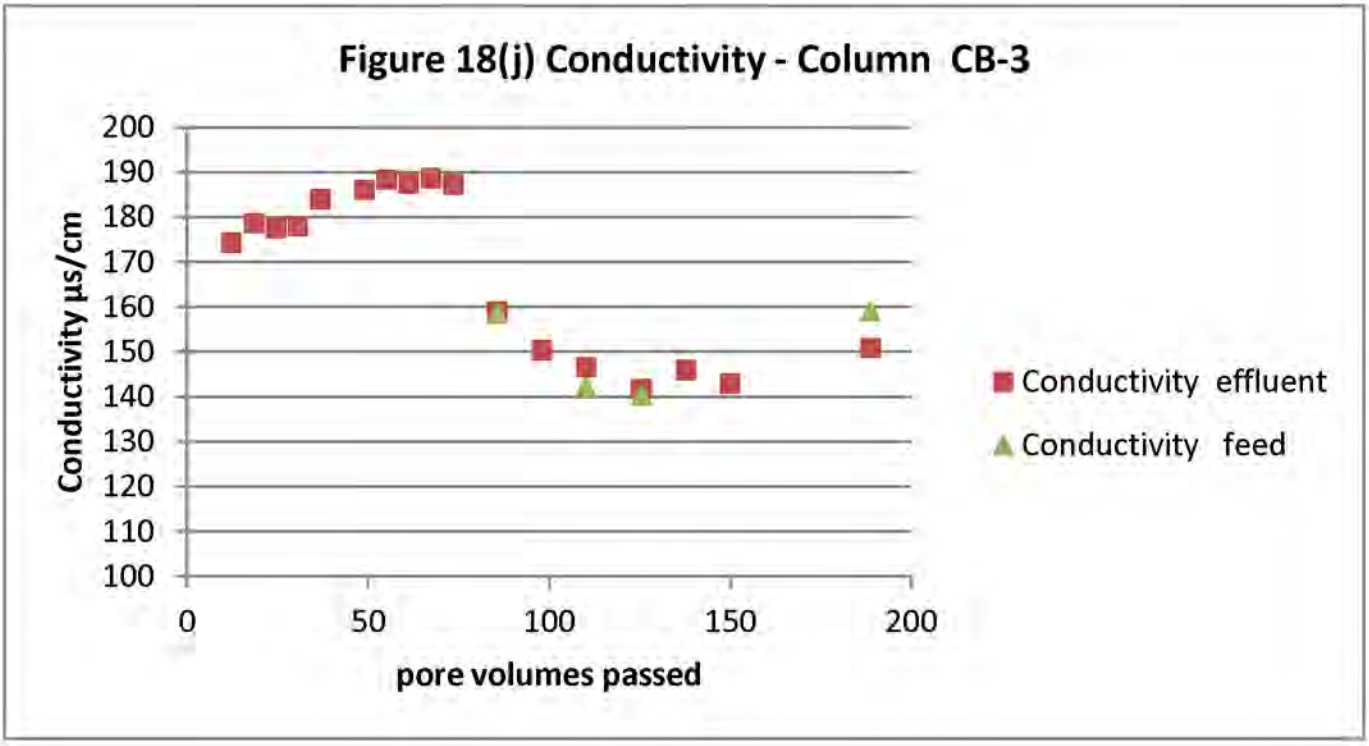


Figure 18(j) Conductivity - Column CB-3
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

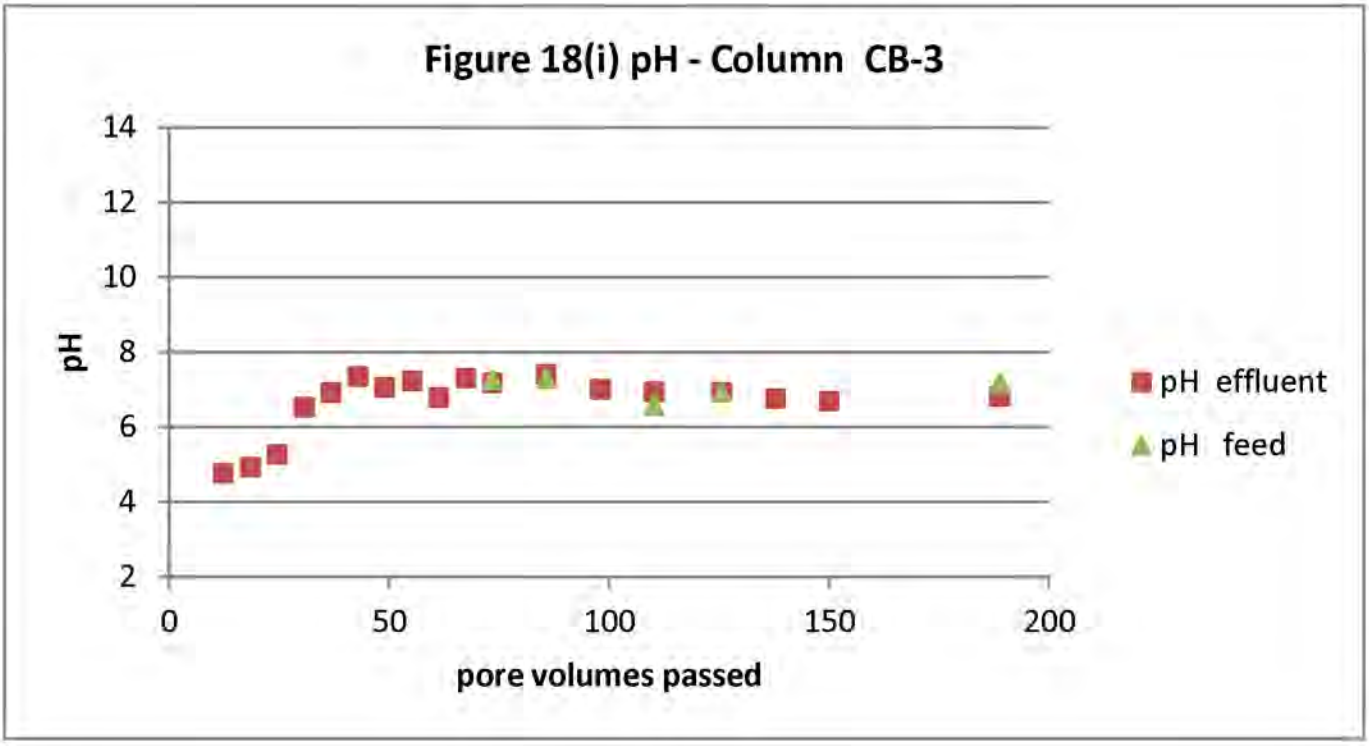


Figure 18(i) pH - Column CB-3
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

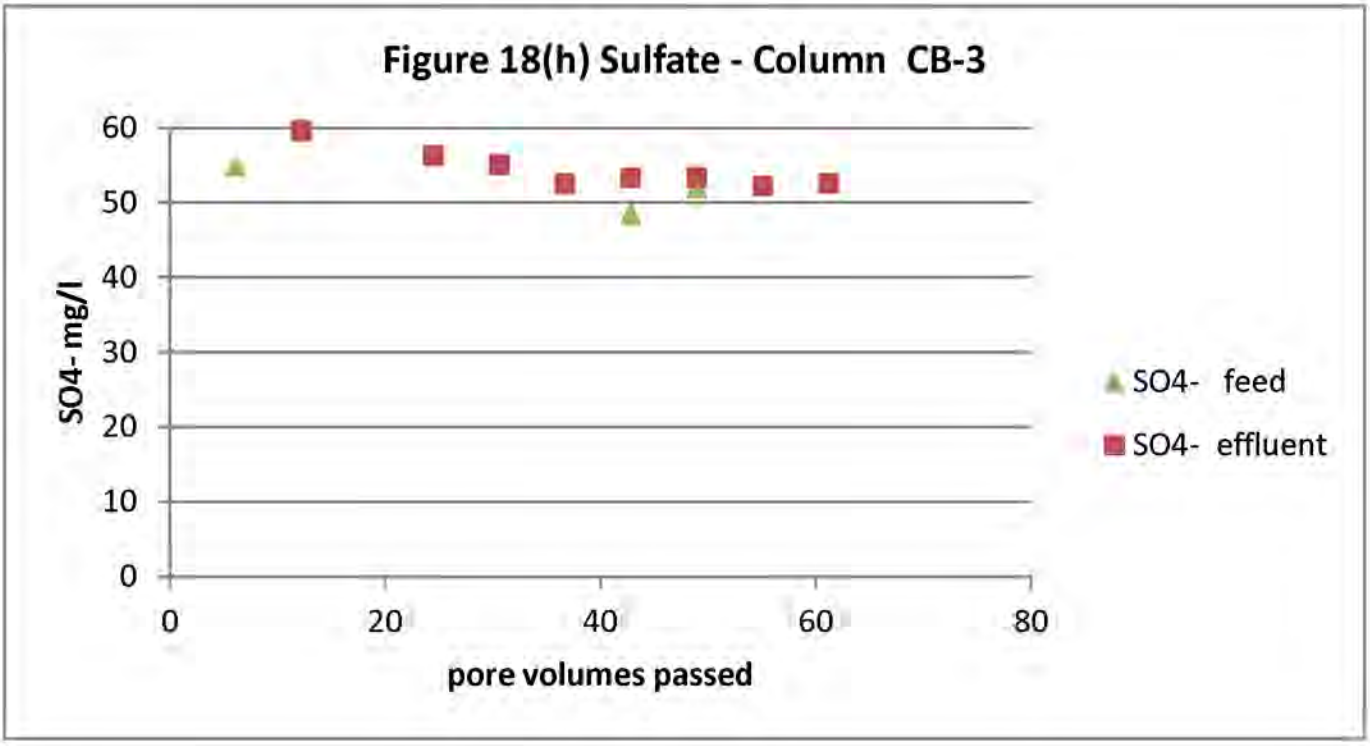


Figure 18(h) Sulfate - Column CB-3
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

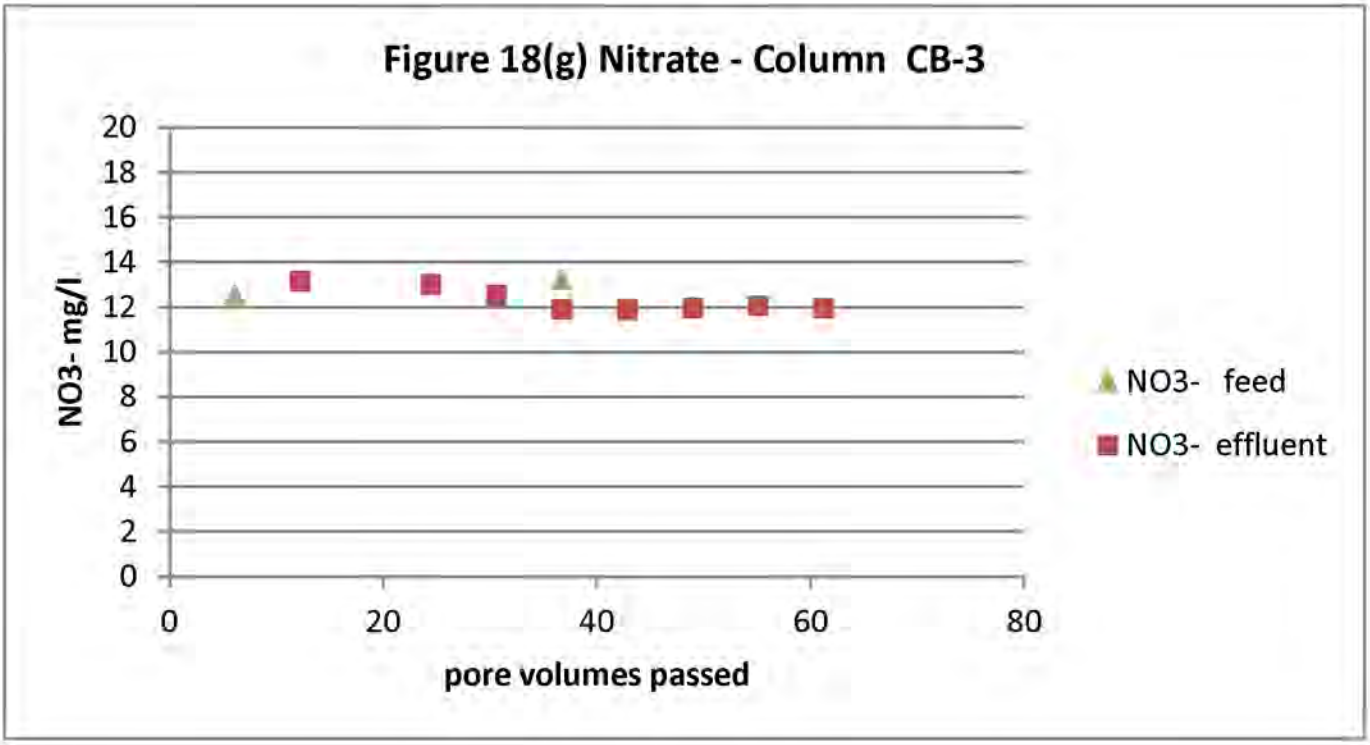


Figure 18(g) Nitrate - Column CB-3
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

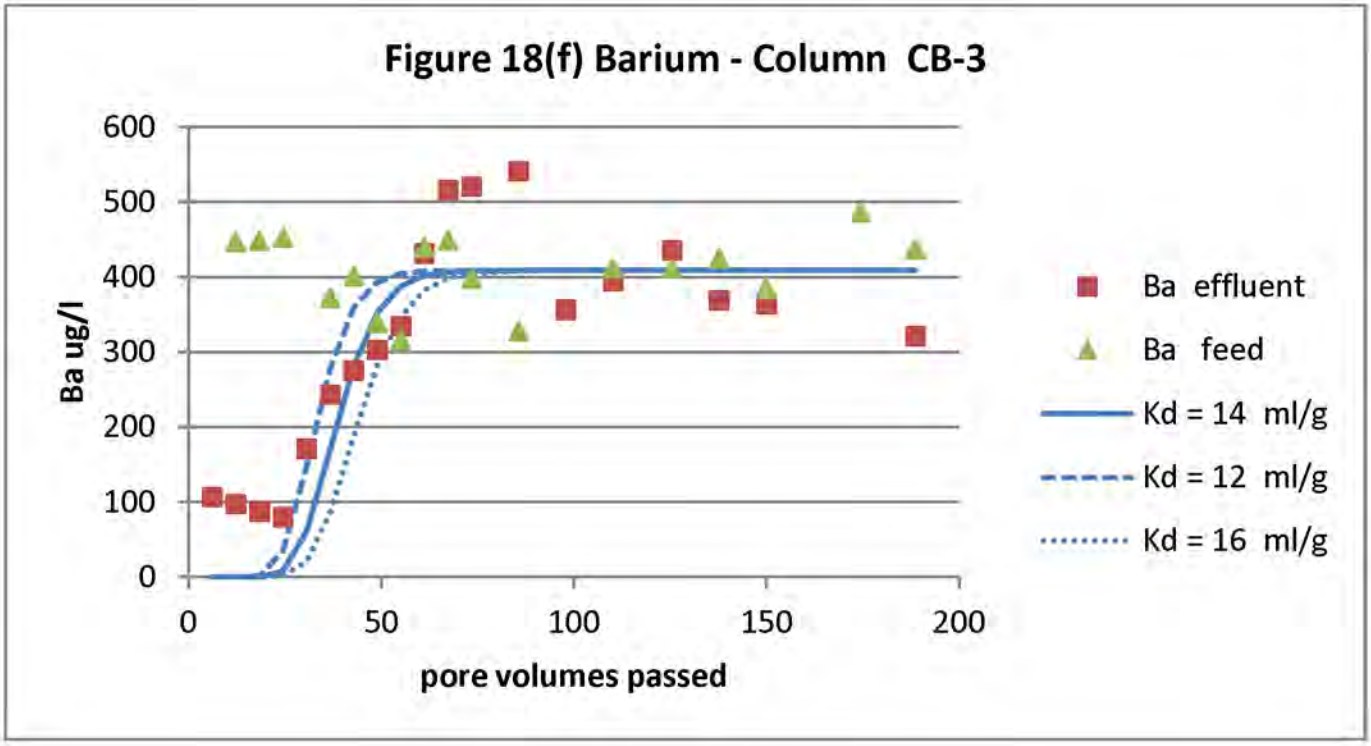


Figure 18(f) Barium - Column CB-3
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 14 ml/g
Kd = 12 ml/g
Kd = 16 ml/g

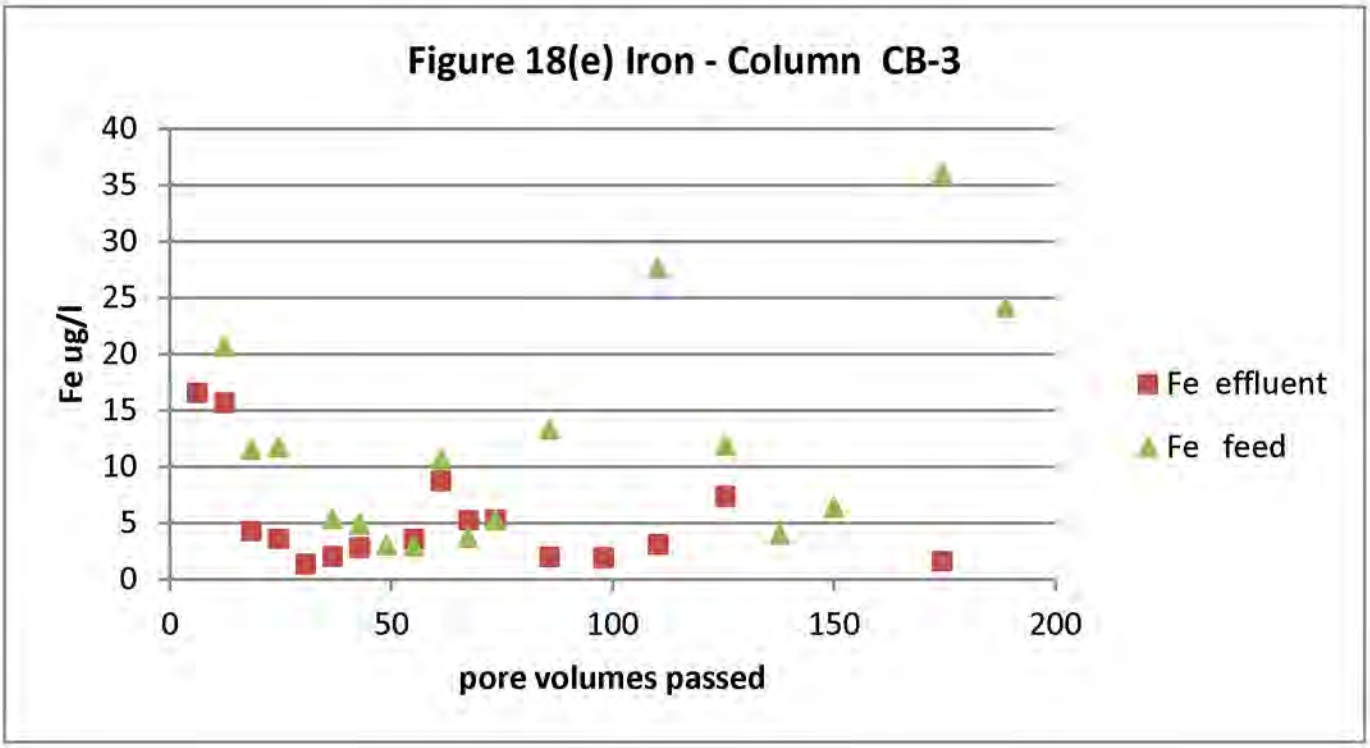


Figure 18(e) Iron - Column CB-3
Fe ug/l
40
35
30
25
20
15
10
5
0
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

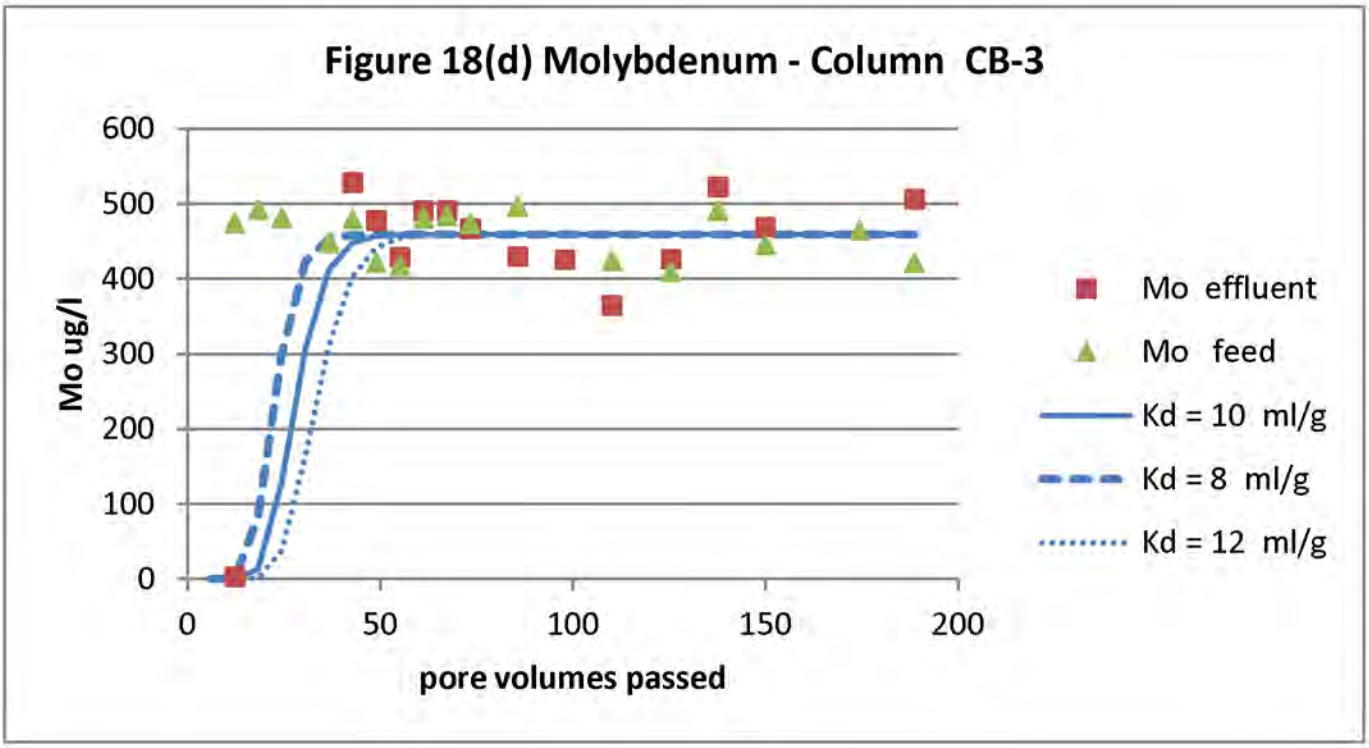


Figure 18(d) Molybdenum - Column CB-3
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 10 ml/g
Kd = 8 ml/g
Kd = 12 ml/g

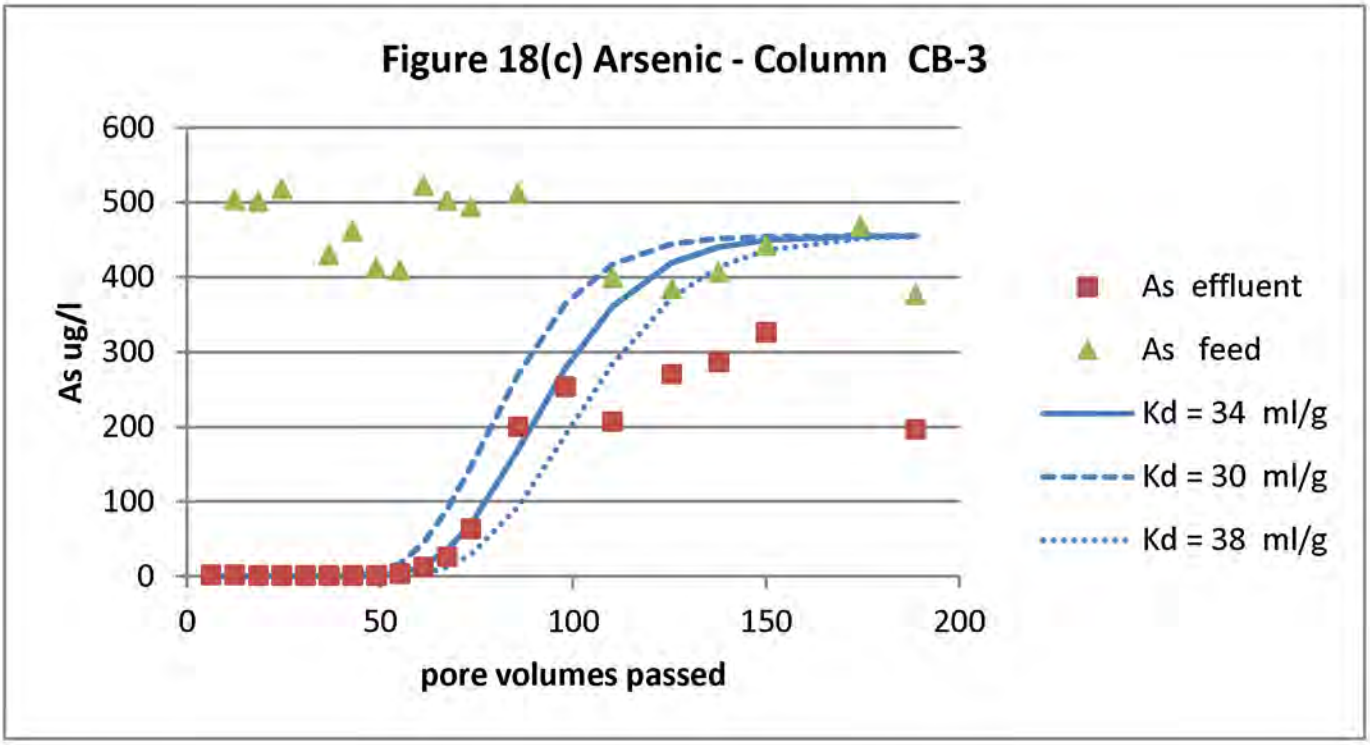


Figure 18(c) Arsenic - Column CB-3
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 34 ml/g
Kd = 30 ml/g
Kd = 38 ml/g

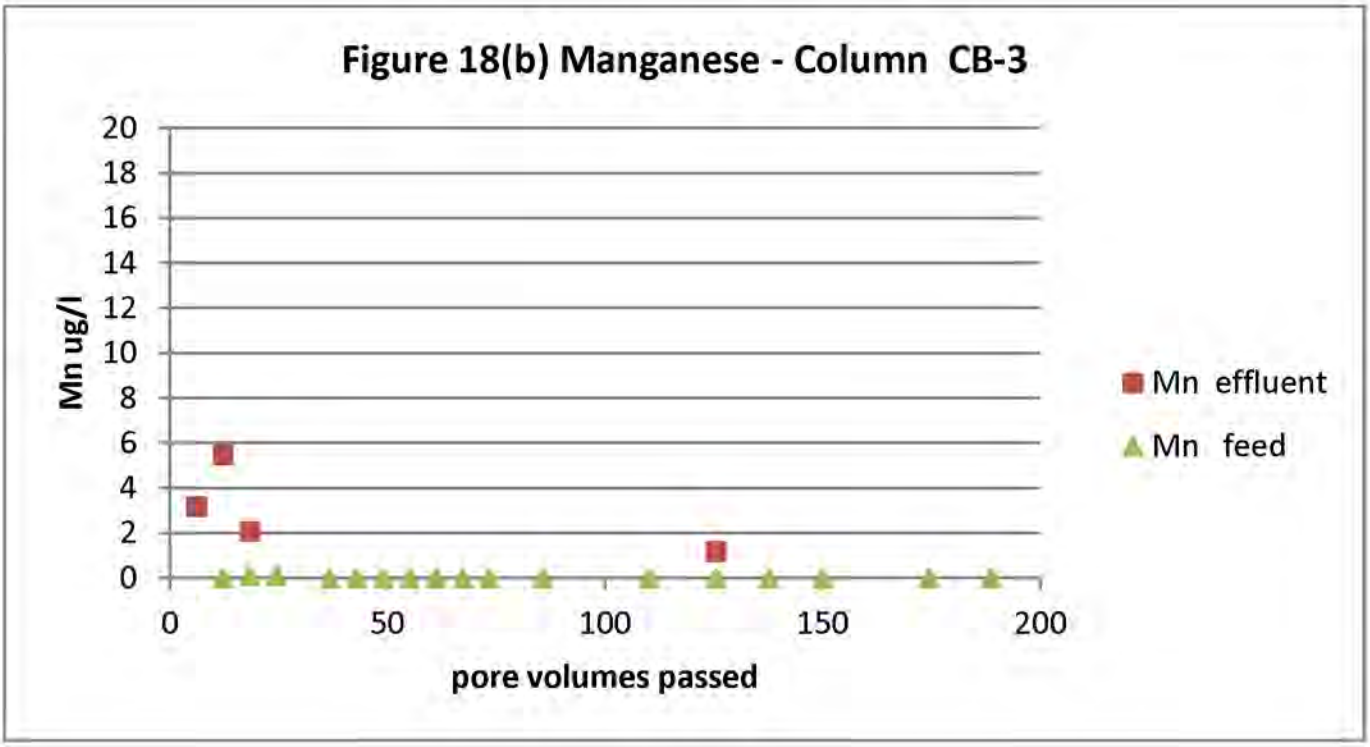


Figure 18(b) Manganese - Column CB-3
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

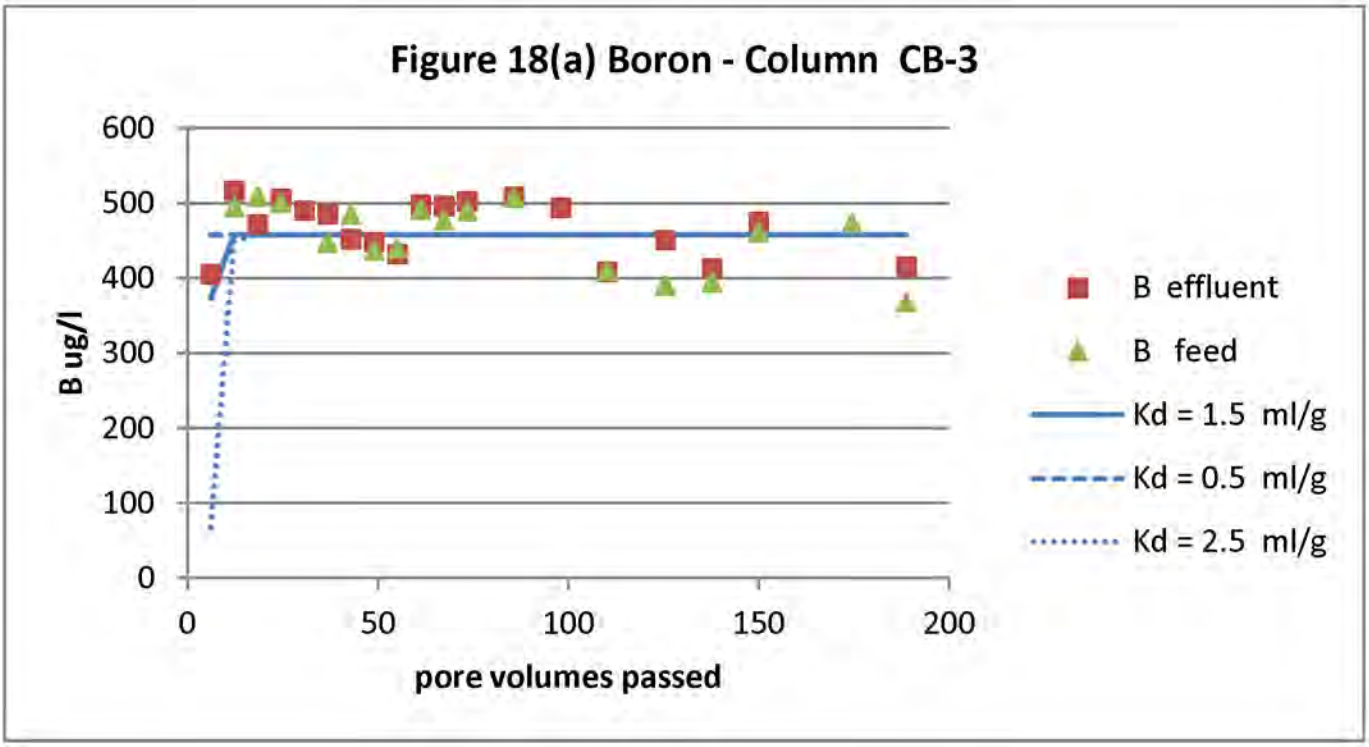


Figure 18(a) Boron - Column CB-3
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 1.5 ml/g
Kd = 0.5 ml/g
Kd = 2.5 ml/g

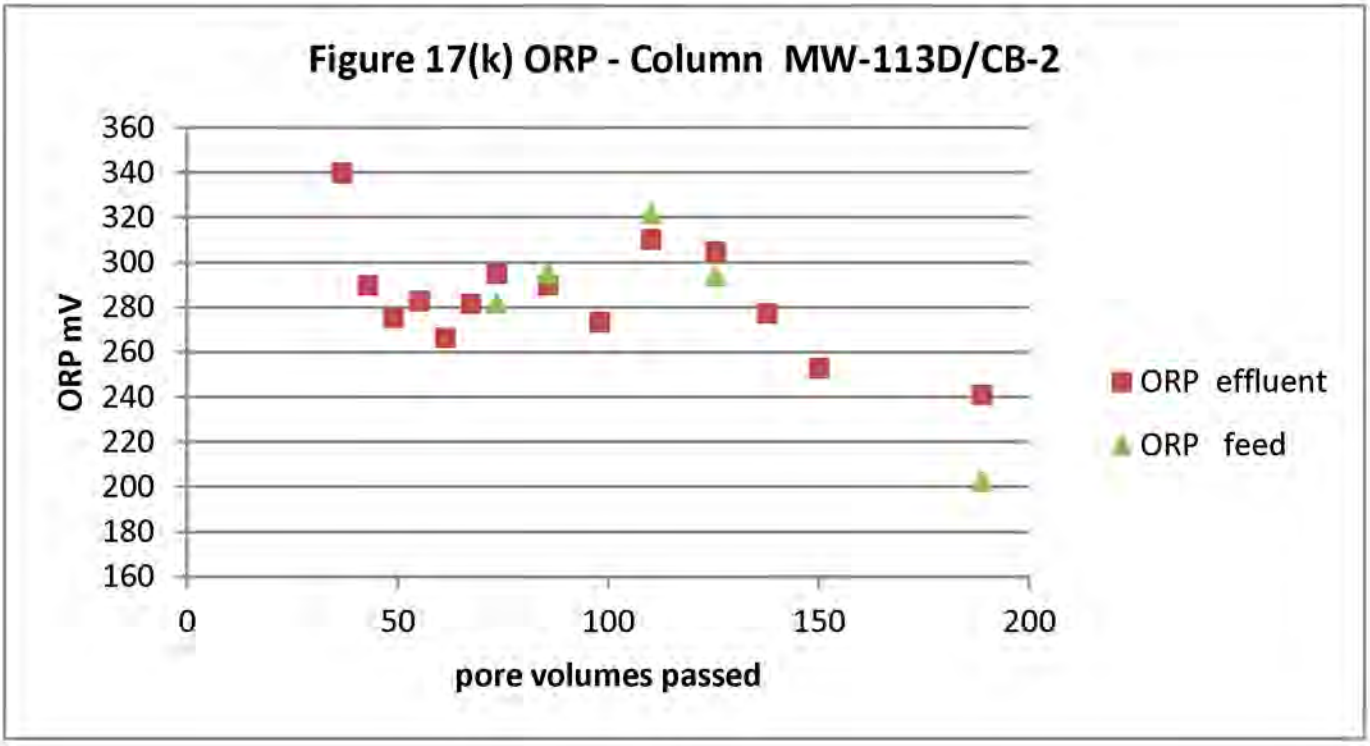


Figure 17(k) ORP - Column MW-113D/CB-2
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

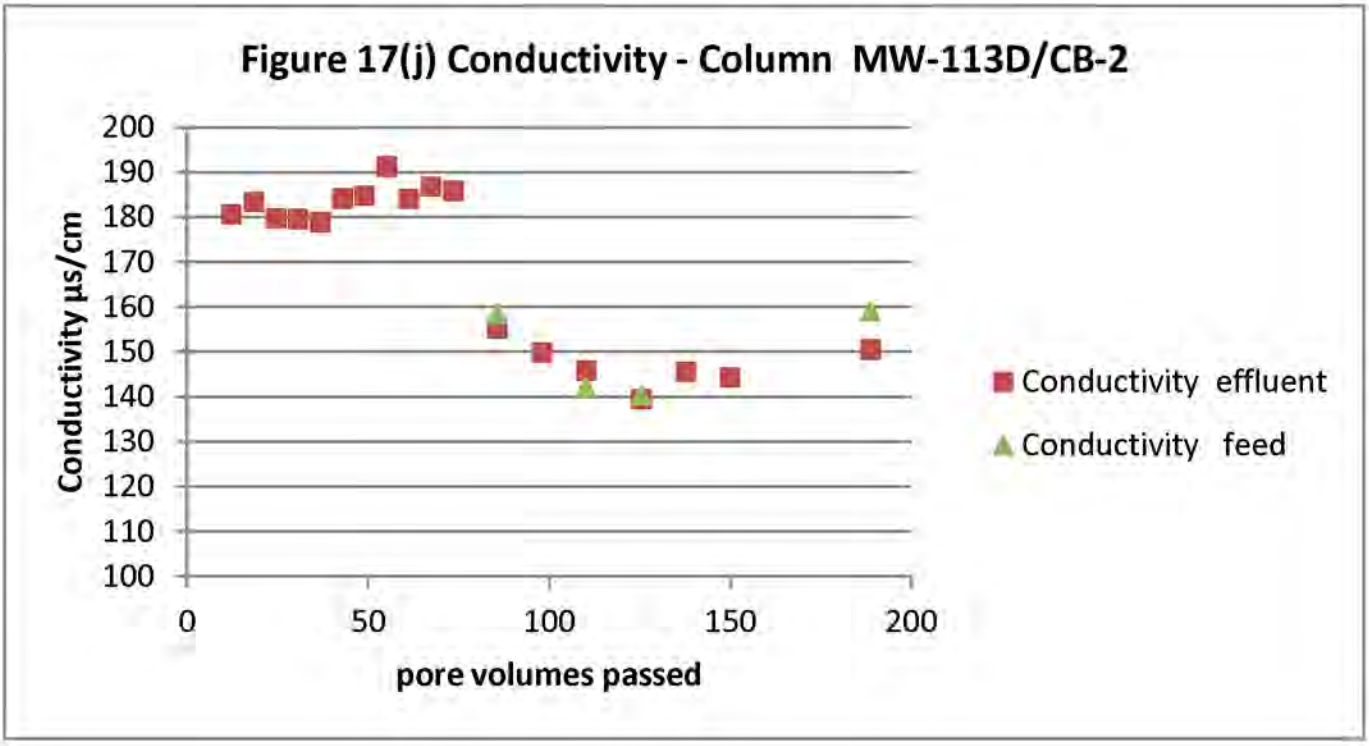


Figure 17(j) Conductivity - Column MW-113D/CB-2
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

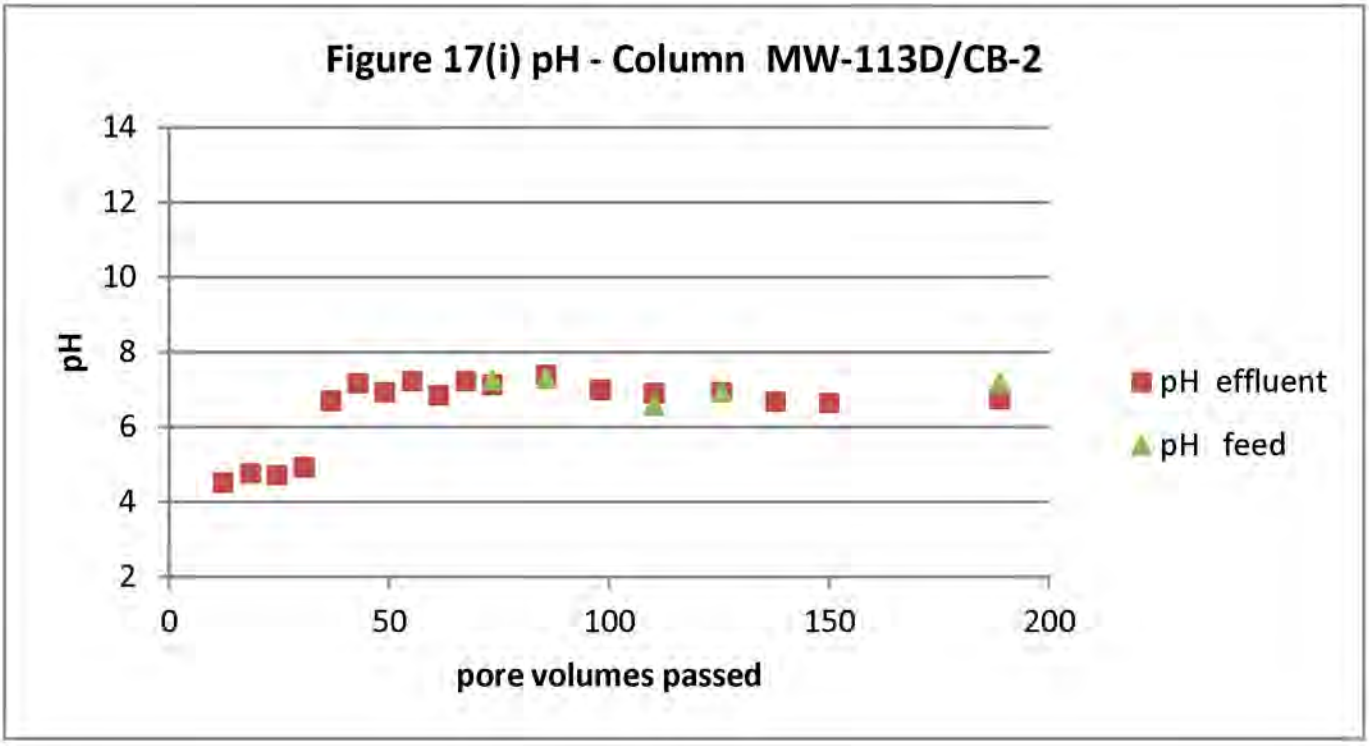


Figure 17(i) pH - Column MW-113D/CB-2
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

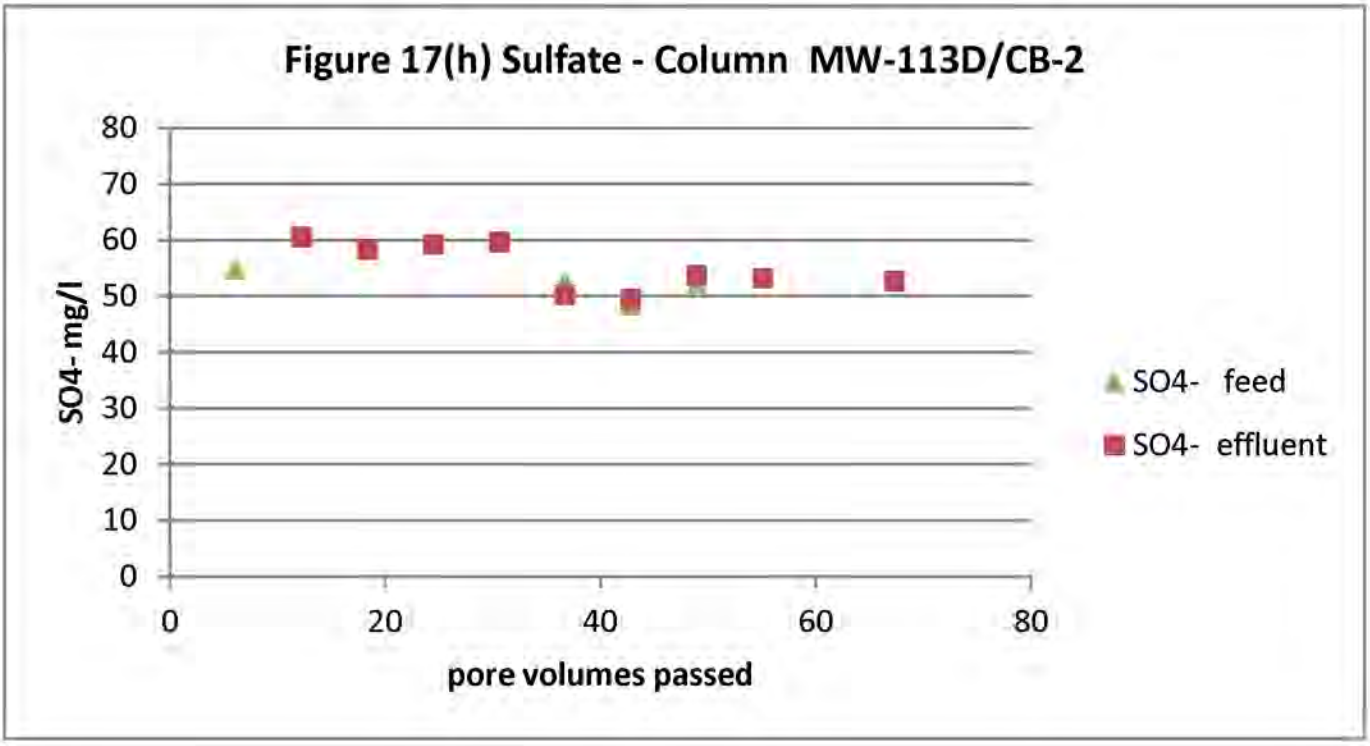


Figure 17(h) Sulfate - Column MW-113D/CB-2
80
70
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

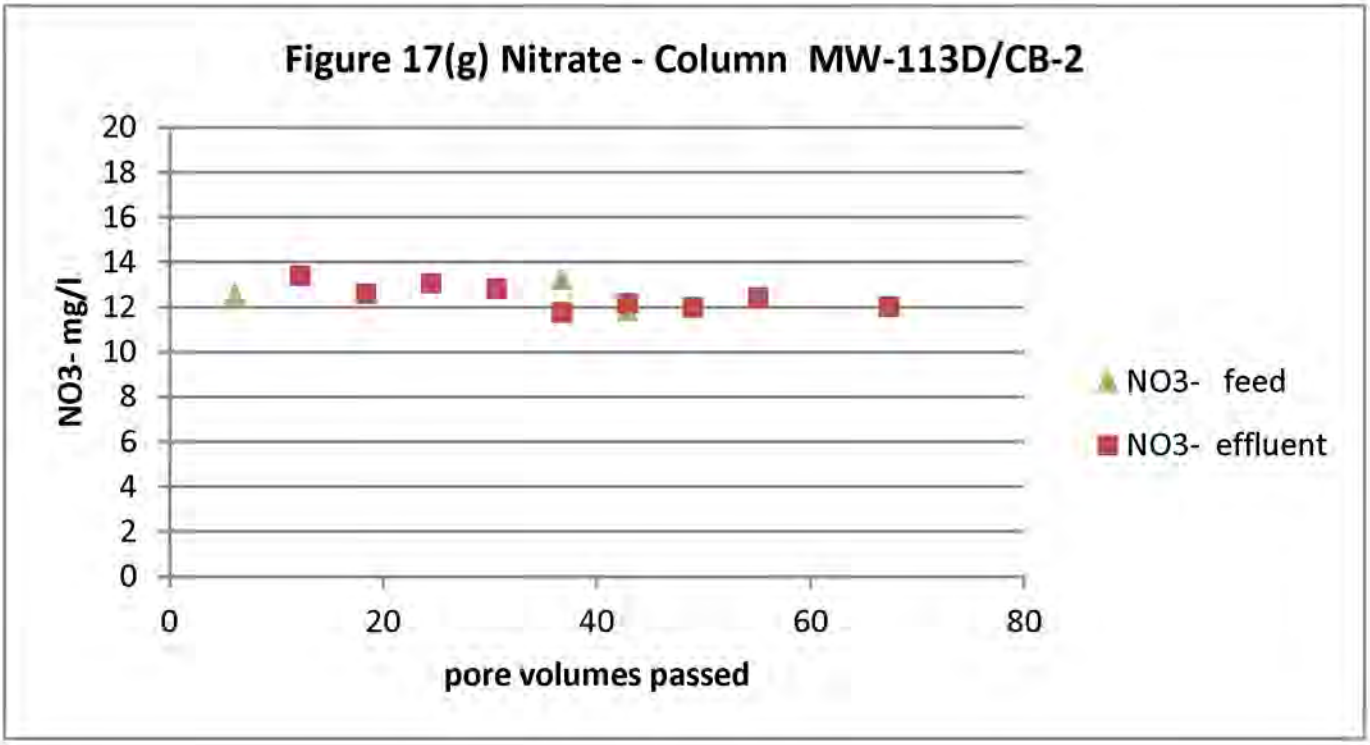


Figure 17(g) Nitrate - Column MW-113D/CB-2
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

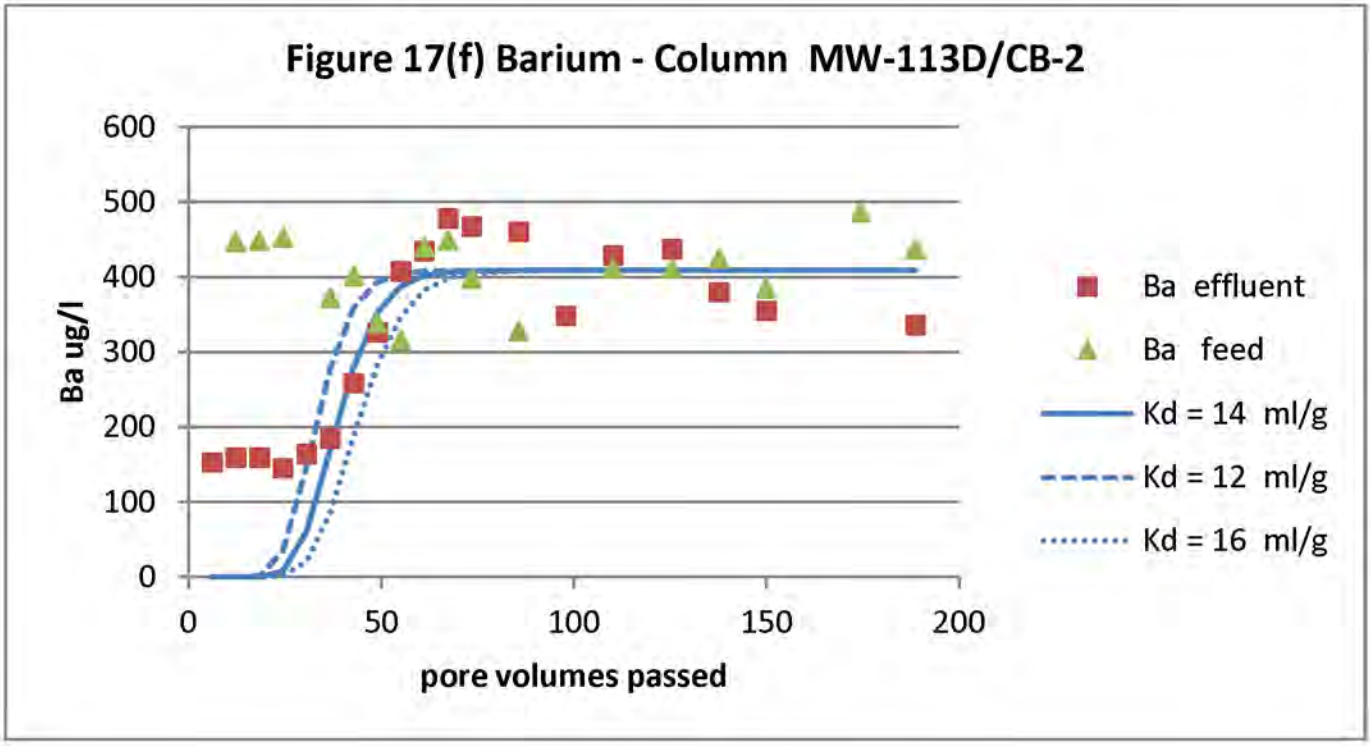


Figure 17(f) Barium - Column MW-113D/CB-2
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 14 ml/g
Kd = 12 ml/g
Kd = 16 ml/g

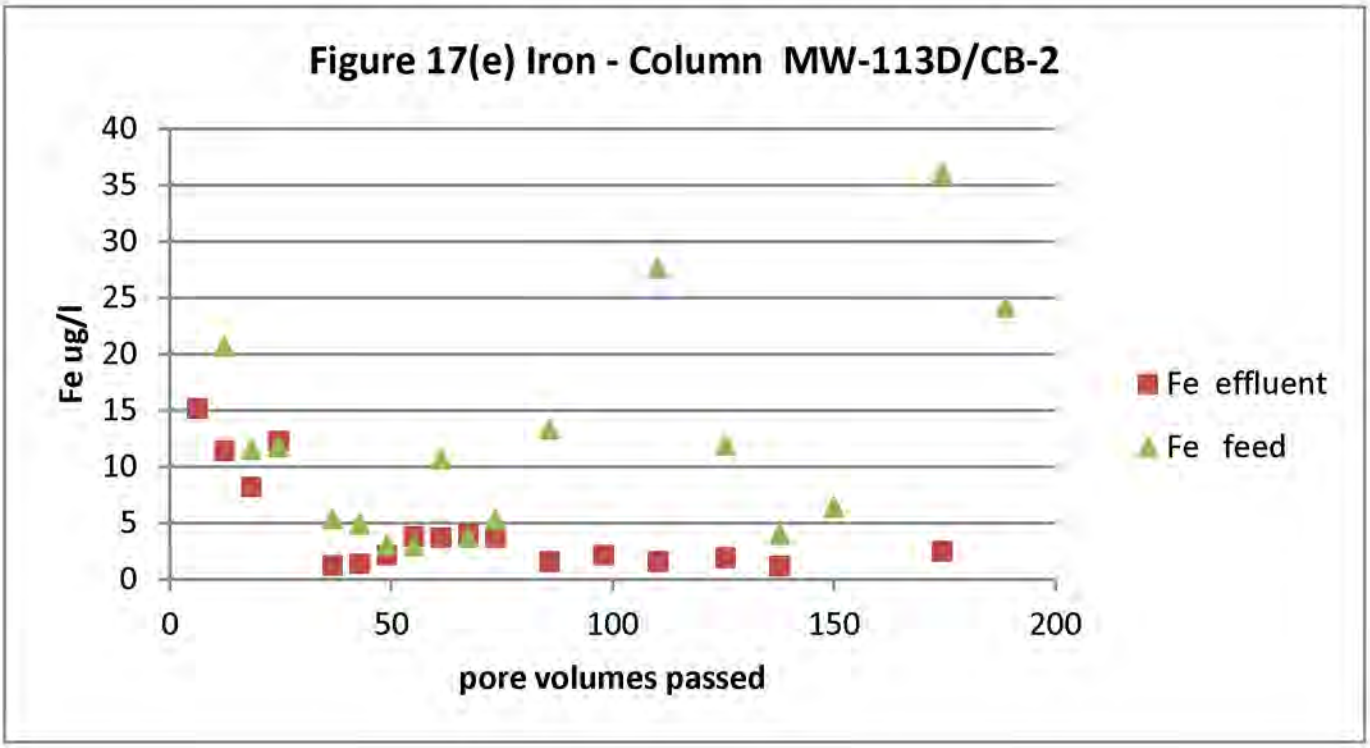


Figure 17(e) Iron - Column MW-113D/CB-2
Fe ug/l
40
35
30
25
20
15
10
5
0
0
50
100
150
200
pore volumes passed
Fe effluent
Fe feed

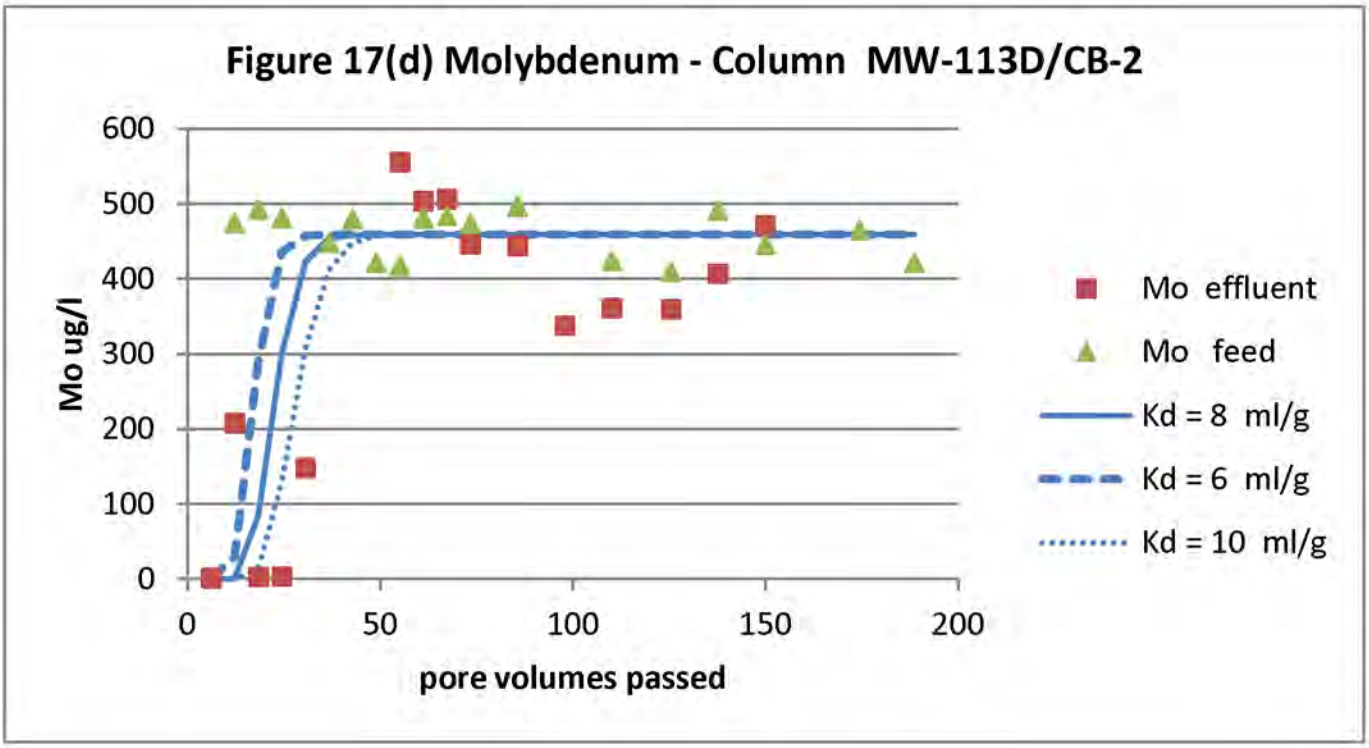


Figure 17(d) Molybdenum - Column MW-113D/CB-2
600
500
400
300
200
100
0
Mo ug/l
0
50
100
150
200
pore volumes passed
Mo effluent
Mo feed
Kd = 8 ml/g
Kd = 6 ml/g
Kd = 10 ml/g

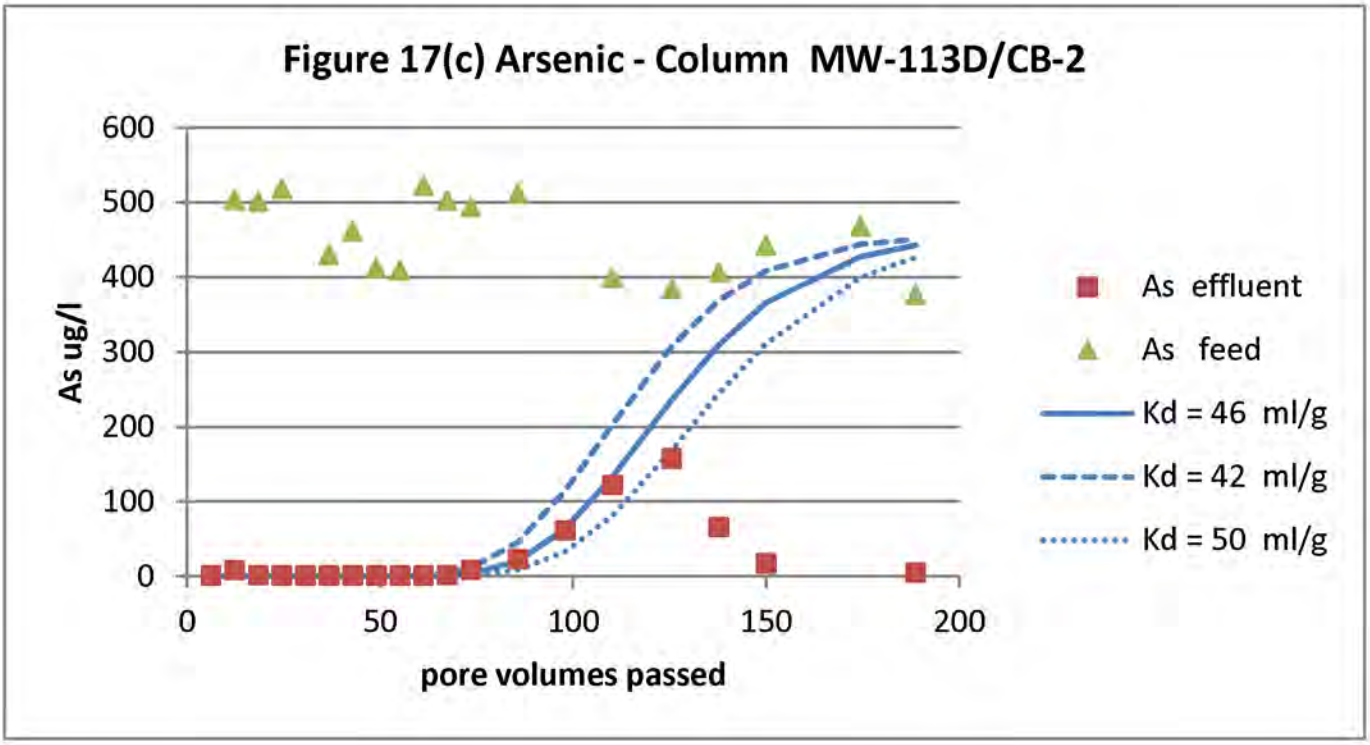


Figure 17(c) Arsenic - Column MW-113D/CB-2
600
500
400
300
200
100
0
As ug/l
0
50
100
150
200
pore volumes passed
As effluent
As feed
Kd = 46 ml/g
Kd = 42 ml/g
Kd = 50 ml/g

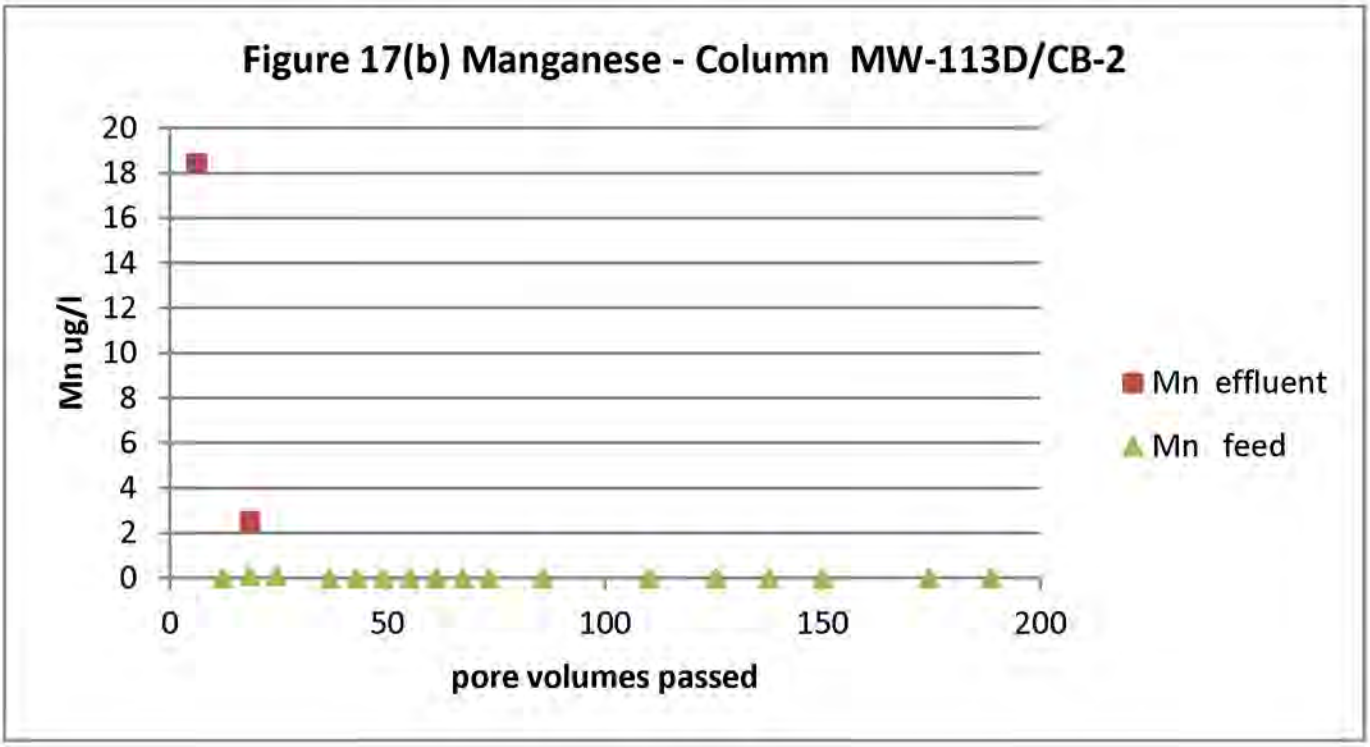


Figure 17(b) Manganese - Column MW-113D/CB-2
Mn ug/l
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
pore volumes passed
Mn effluent
Mn feed

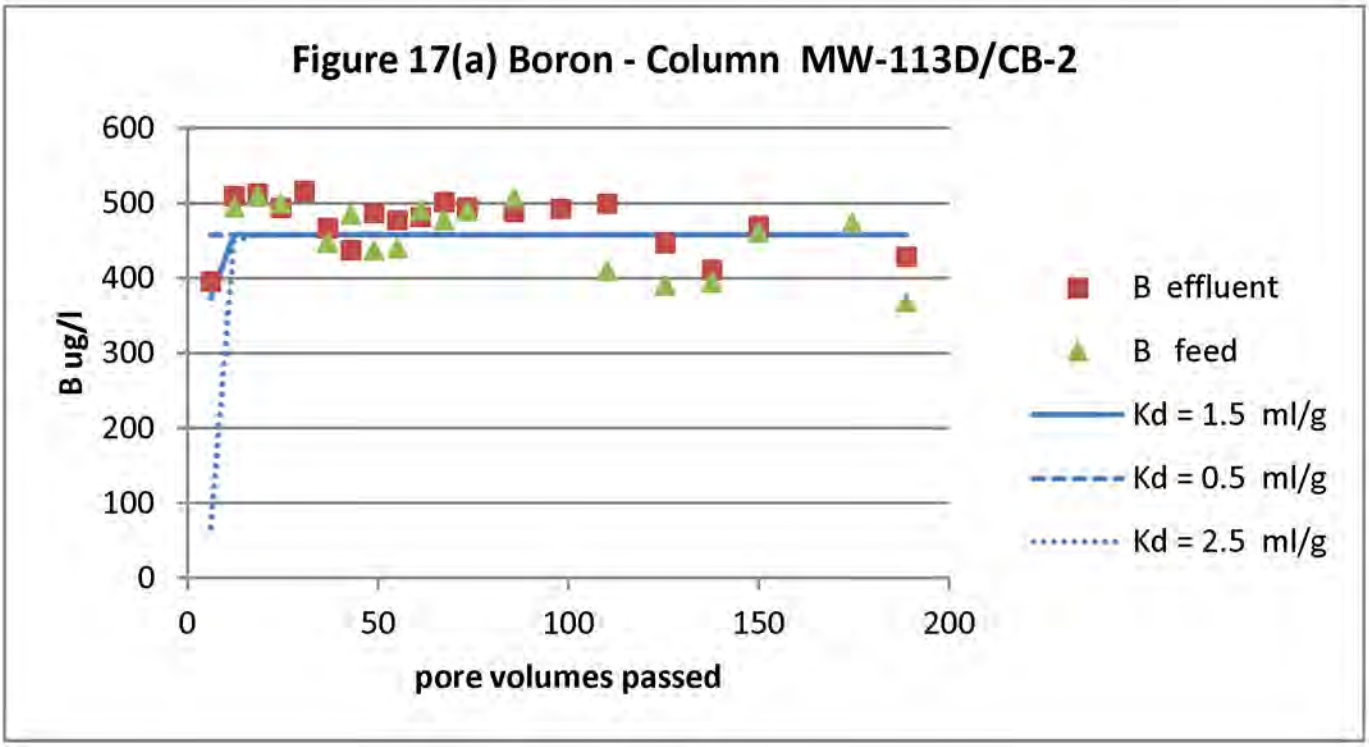


Figure 17(a) Boron - Column MW-113D/CB-2
600
500
400
300
200
100
0
B ug/l
0
50
100
150
200
pore volumes passed
B effluent
B feed
Kd = 1.5 ml/g
Kd = 0.5 ml/g
Kd = 2.5 ml/g

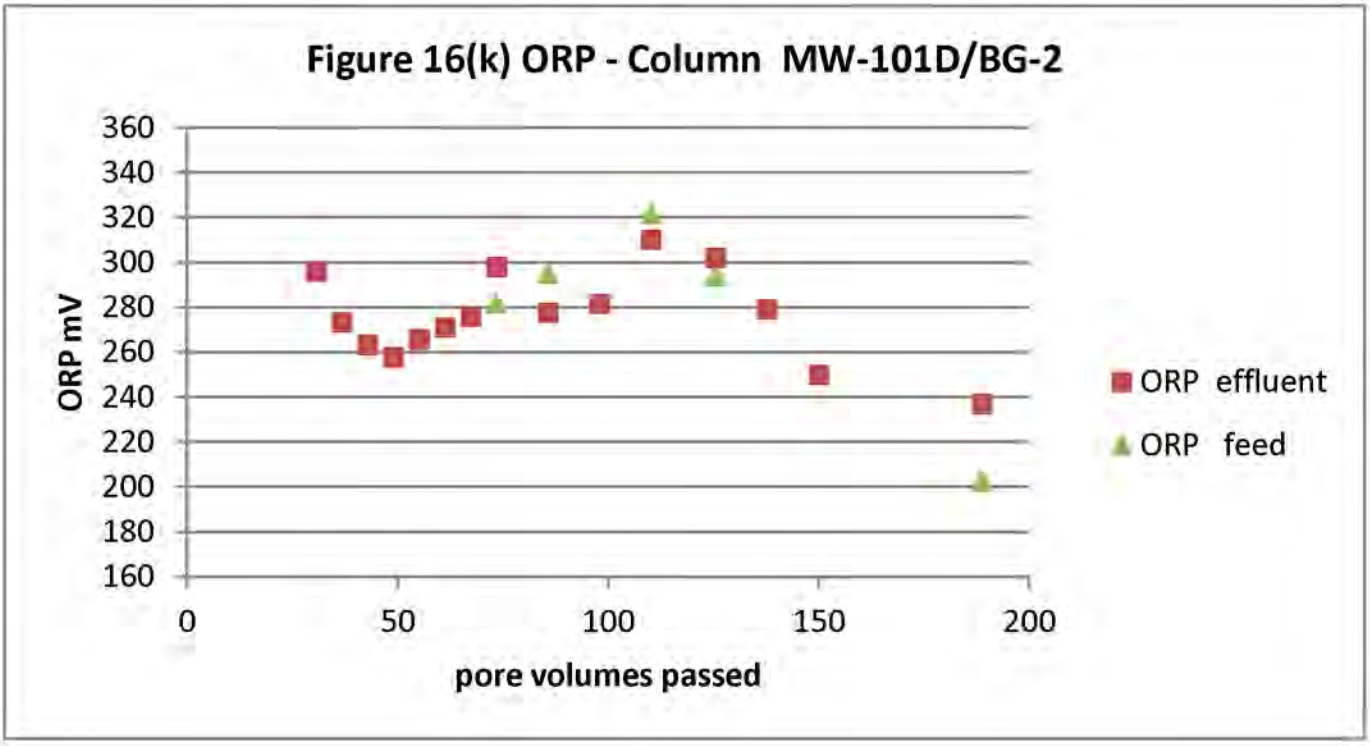


Figure 16(k) ORP - Column MW-101D/BG-2
360
340
320
300
280
260
240
220
200
180
160
ORP mV
0
50
100
150
200
pore volumes passed
ORP effluent
ORP feed

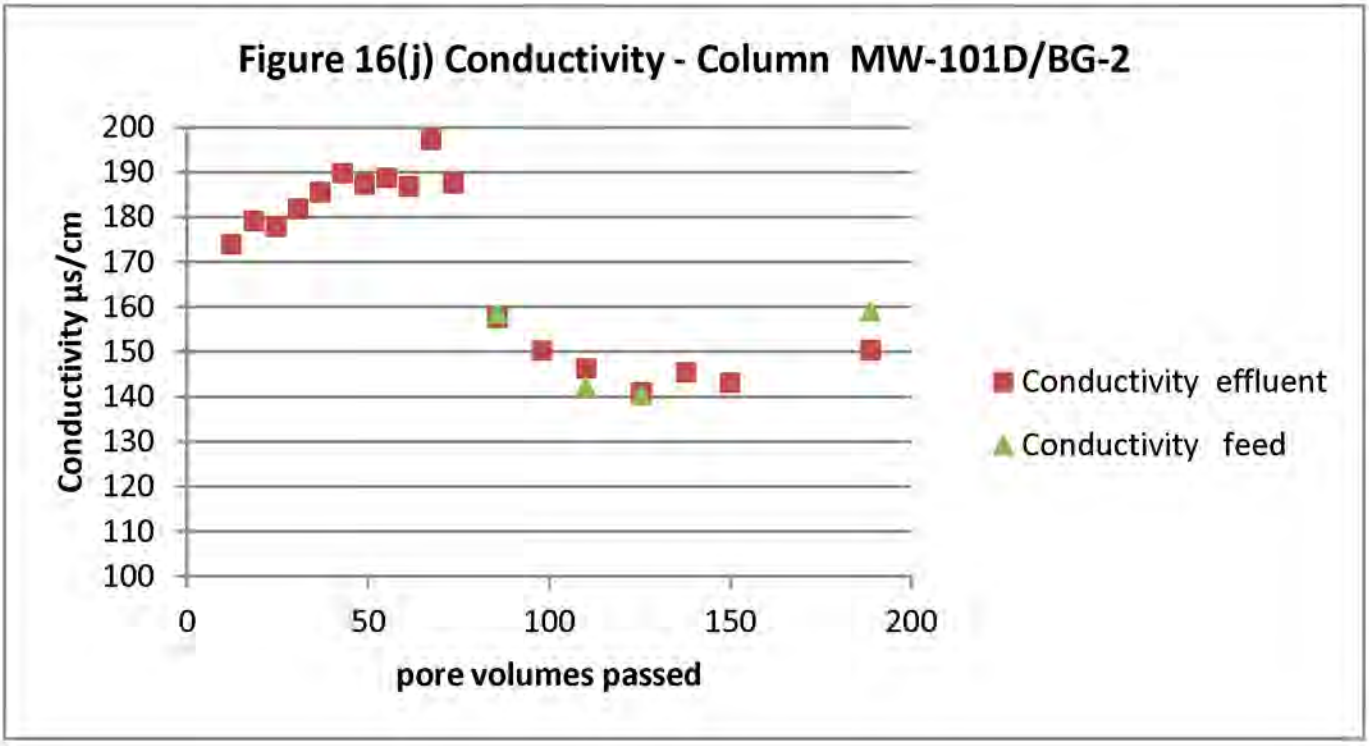


Figure 16(j) Conductivity - Column MW-101D/BG-2
Conductivity µs/cm
200
190
180
170
160
150
140
130
120
110
100
0
50
100
150
200
pore volumes passed
Conductivity effluent
Conductivity feed

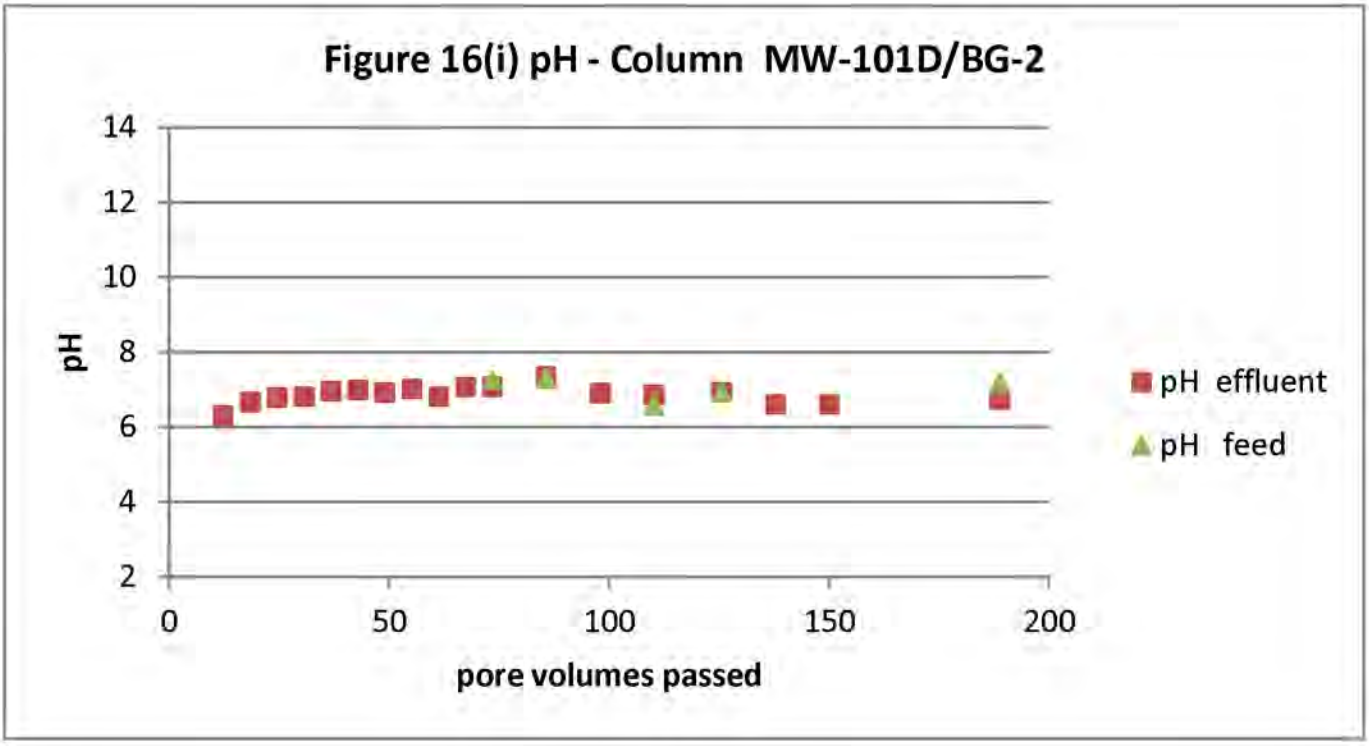


Figure 16(i) pH - Column MW-101D/BG-2
14
12
10
8
6
4
2
pH
0
50
100
150
200
pore volumes passed
pH effluent
pH feed

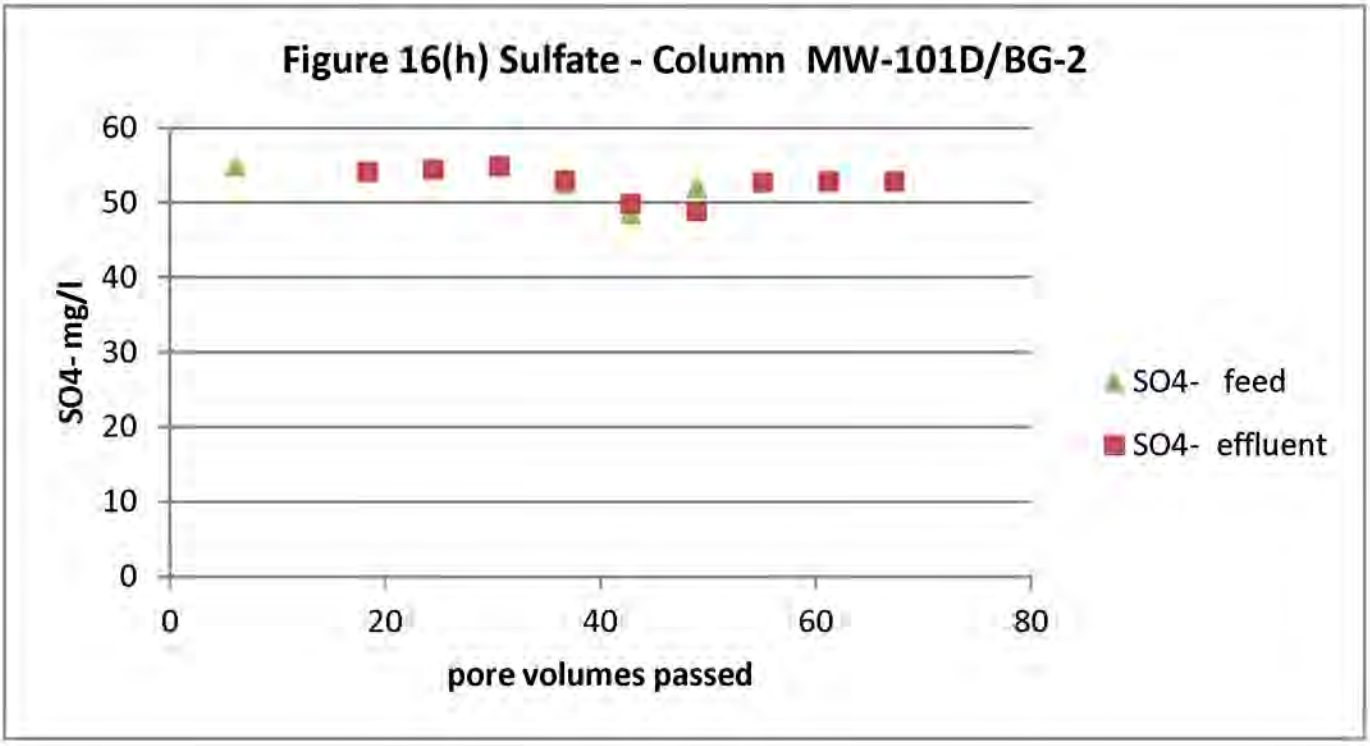


Figure 16(h) Sulfate - Column MW-101D/BG-2
60
50
40
30
20
10
0
SO4- mg/l
0
20
40
60
80
pore volumes passed
SO4- feed
SO4- effluent

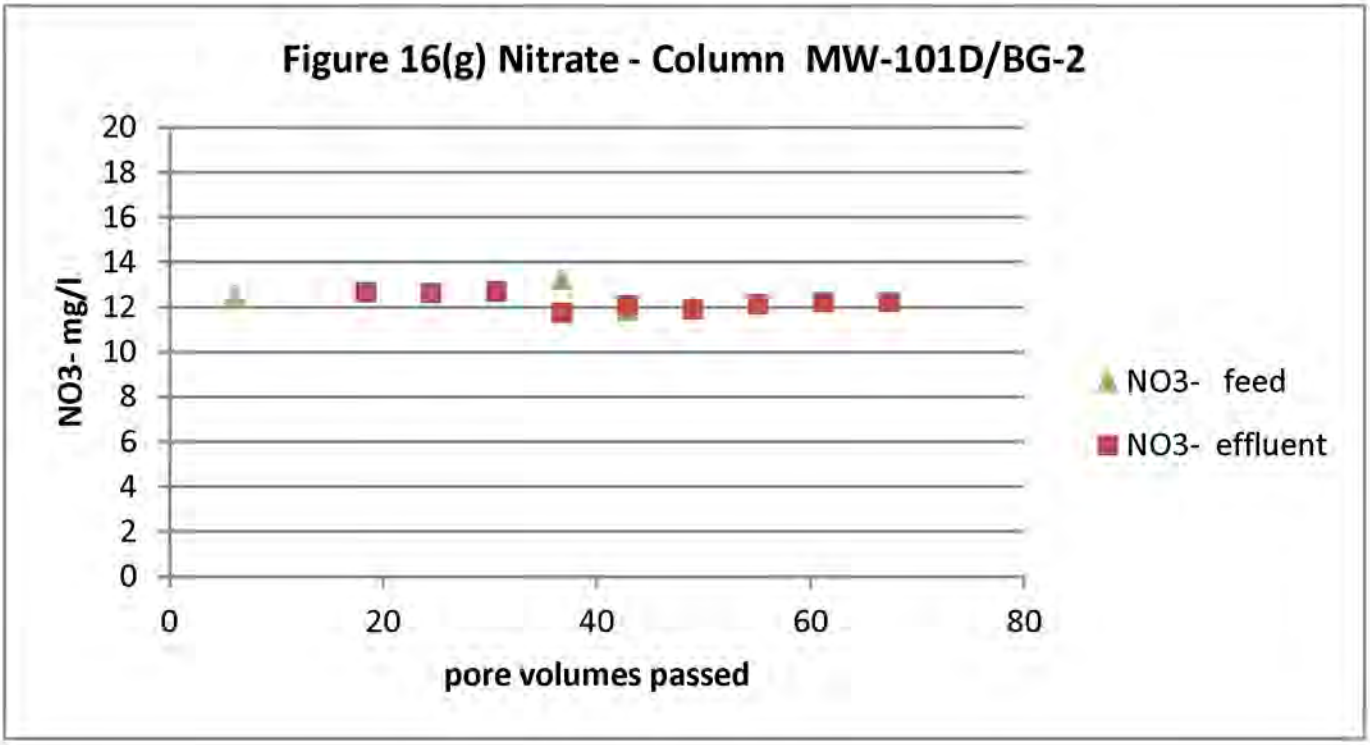


Figure 16(g) Nitrate - Column MW-101D/BG-2
NO3- mg/l
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
pore volumes passed
NO3- feed
NO3- effluent

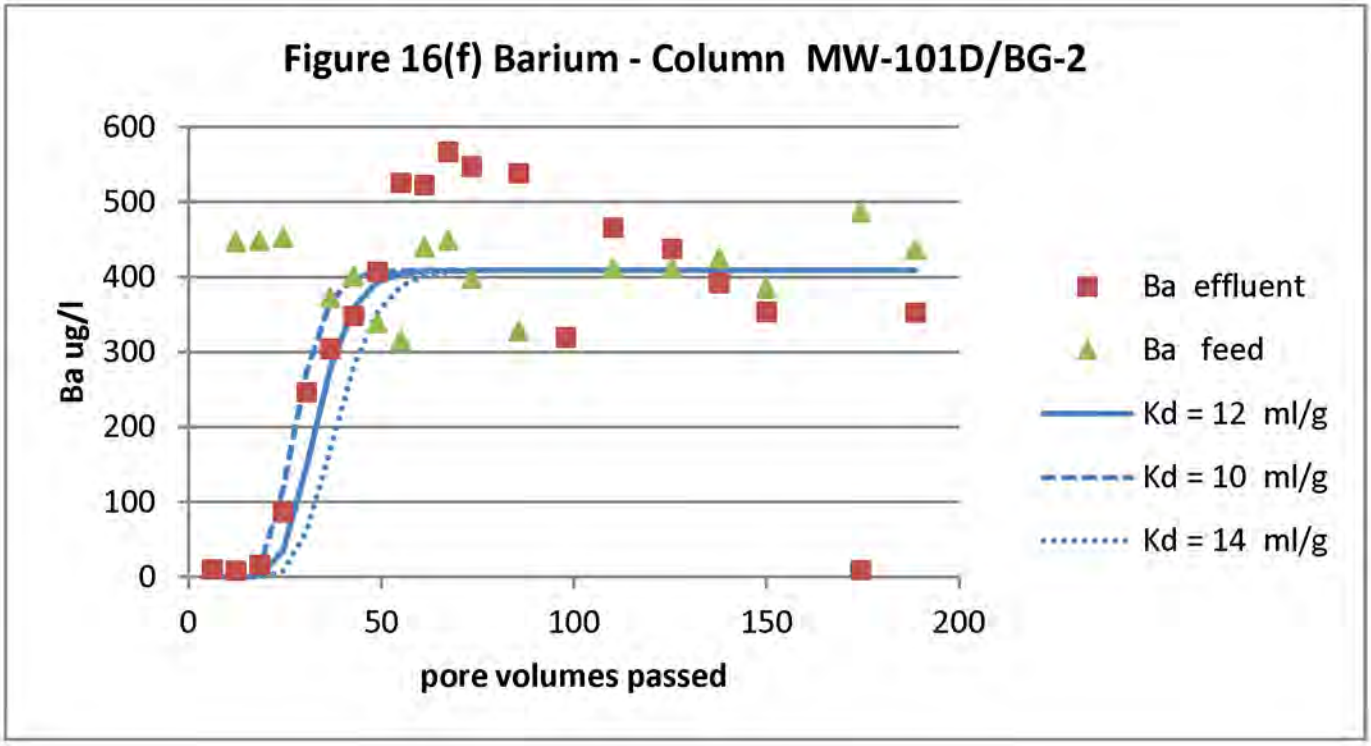


Figure 16(f) Barium - Column MW-101D/BG-2
600
500
400
300
200
100
0
Ba ug/l
0
50
100
150
200
pore volumes passed
Ba effluent
Ba feed
Kd = 12 ml/g
Kd = 10 ml/g
Kd = 14 ml/g

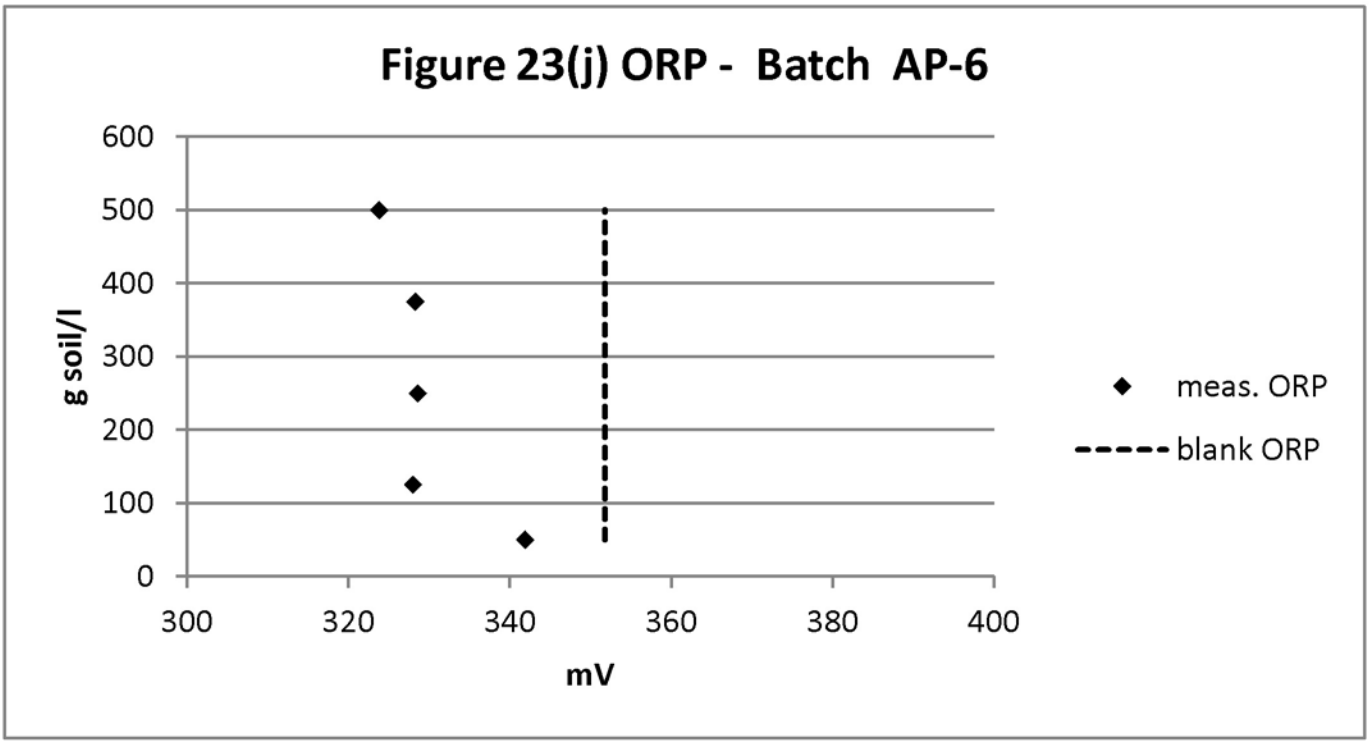


Figure 23(j) ORP - Batch AP-6
600
500
400
300
200
100
0
g soil/l
300
320
340
360
380
400
mV
meas. ORP
blank ORP

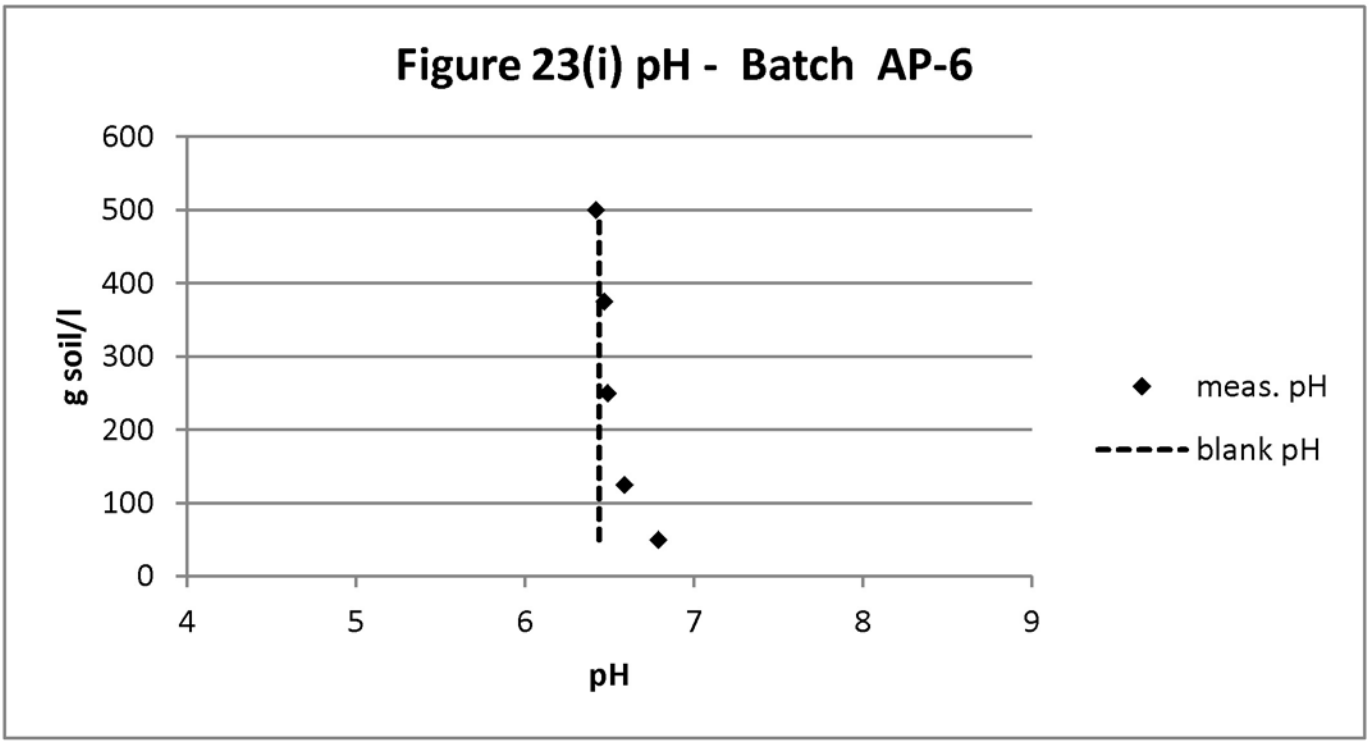


Figure 23(i) pH - Batch AP-6
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

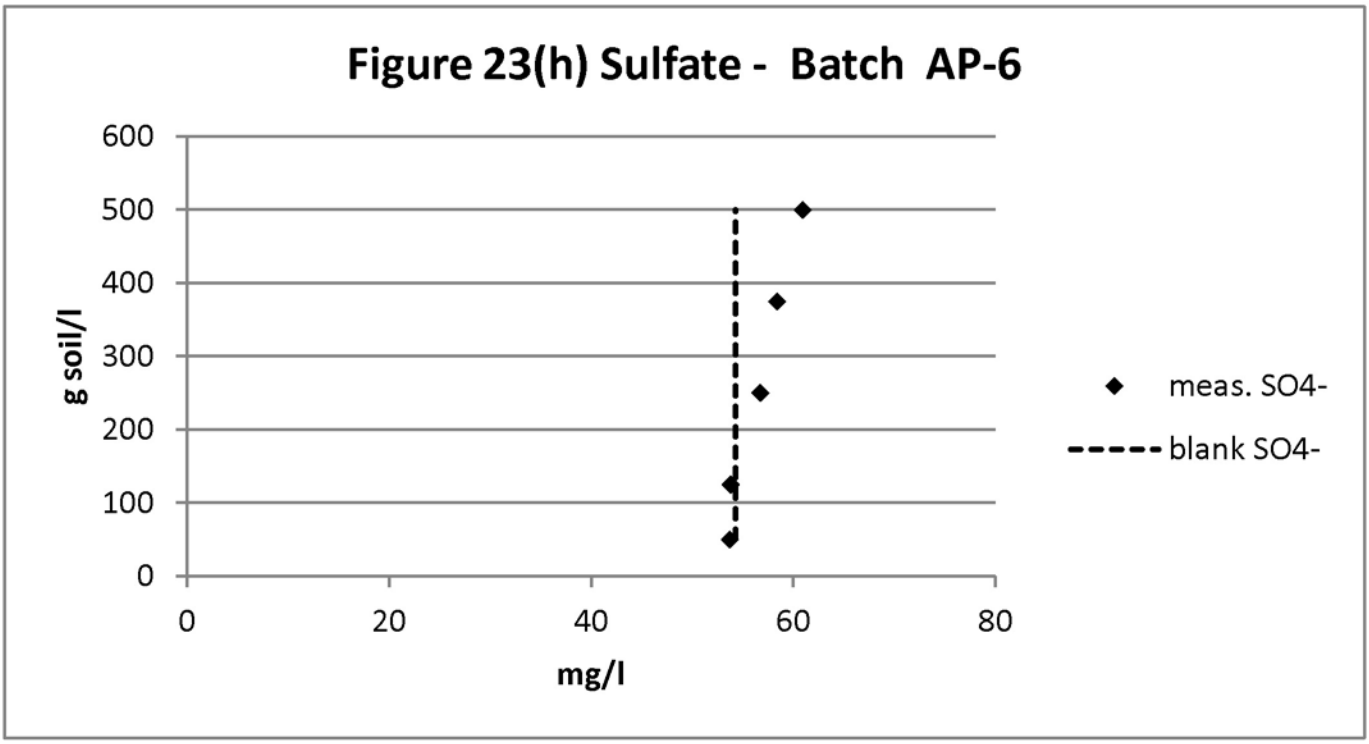


Figure 23(h) Sulfate - Batch AP-6
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

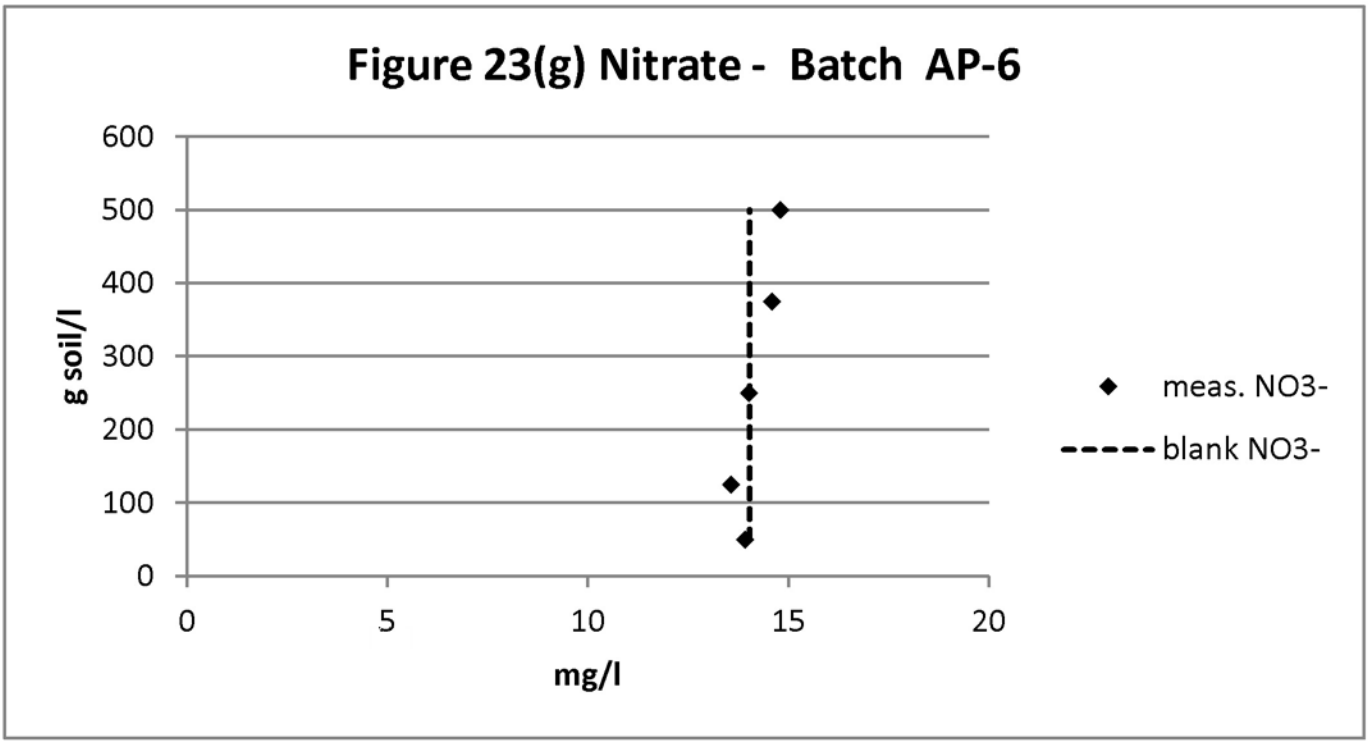


Figure 23(g) Nitrate - Batch AP-6
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

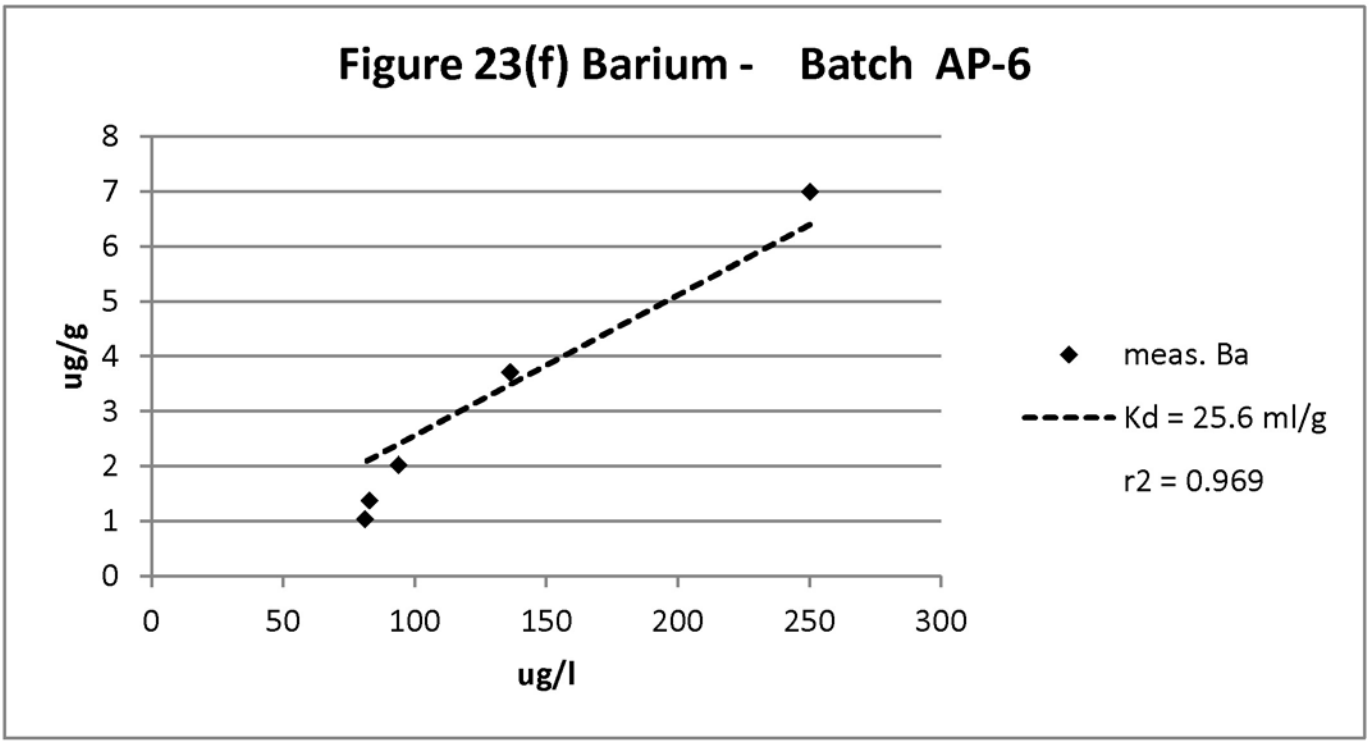


Figure 23(f) Barium - Batch AP-6
ug/g
ug/l
0
1
2
3
4
5
6
7
8
0
50
100
150
200
250
300
meas. Ba
Kd = 25.6 ml/g
r2 = 0.969

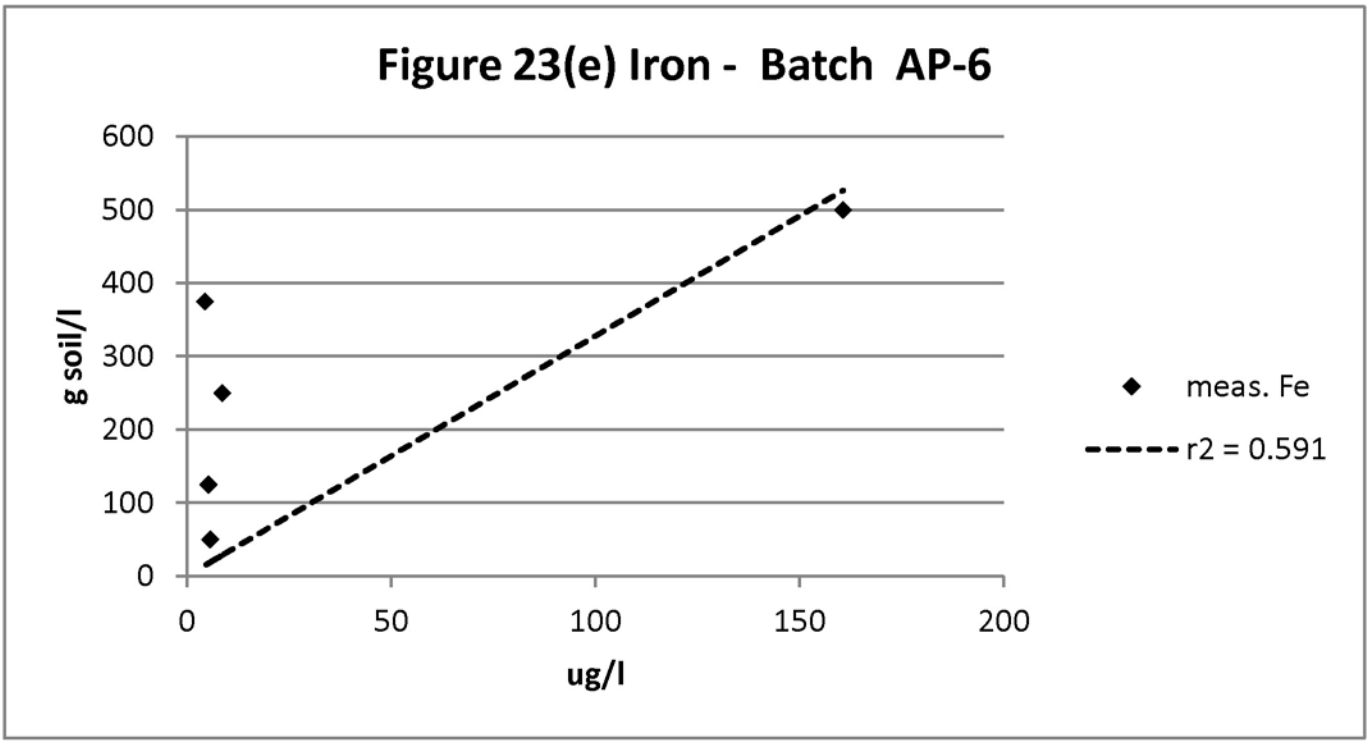


Figure 23(e) Iron - Batch AP-6
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
ug/l
meas. Fe
r2 = 0.591

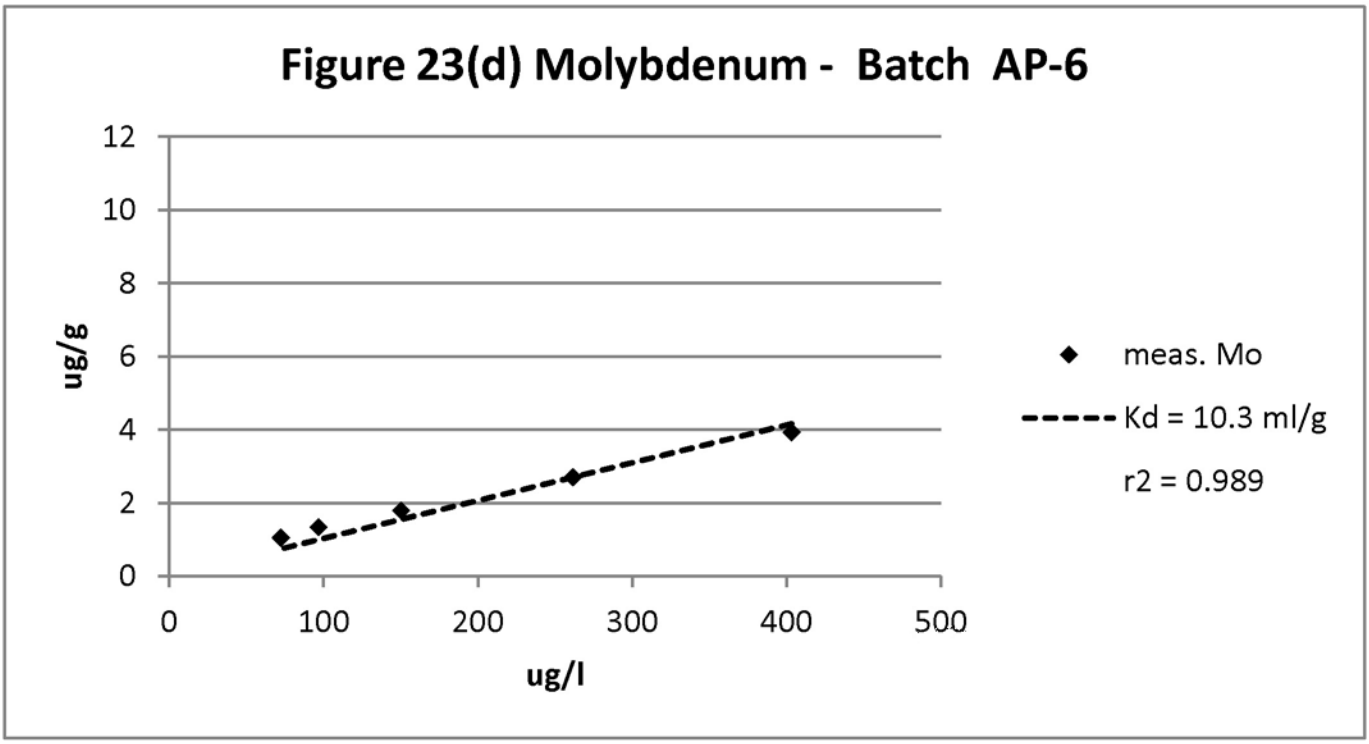


Figure 23(d) Molybdenum - Batch AP-6
12
10
8
6
4
2
0
ug/g
0
100
200
300
400
500
ug/l
meas. Mo
Kd = 10.3 ml/g
r2 = 0.989

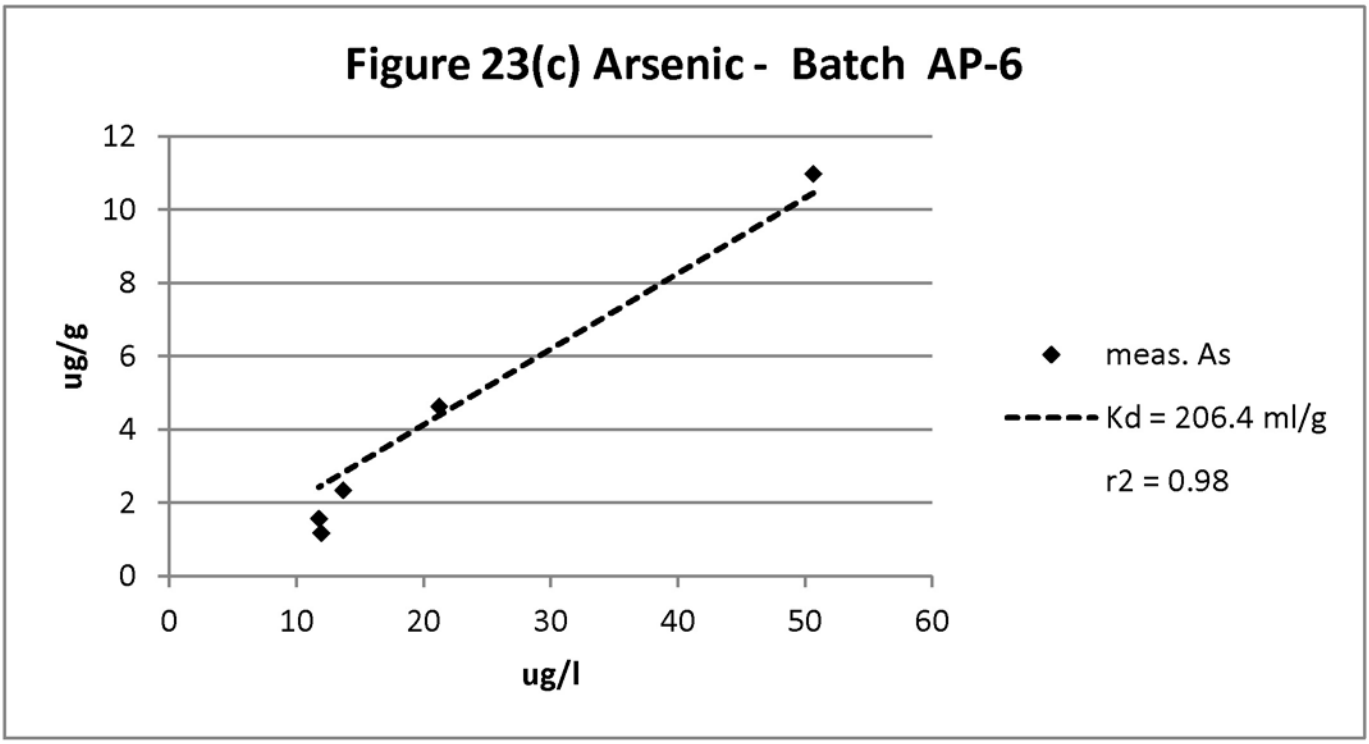


Figure 23(c) Arsenic - Batch AP-6
12
10
8
6
4
2
0
ug/g
0
10
20
30
40
50
60
ug/l
meas. As
Kd = 206.4 ml/g
r2 = 0.98

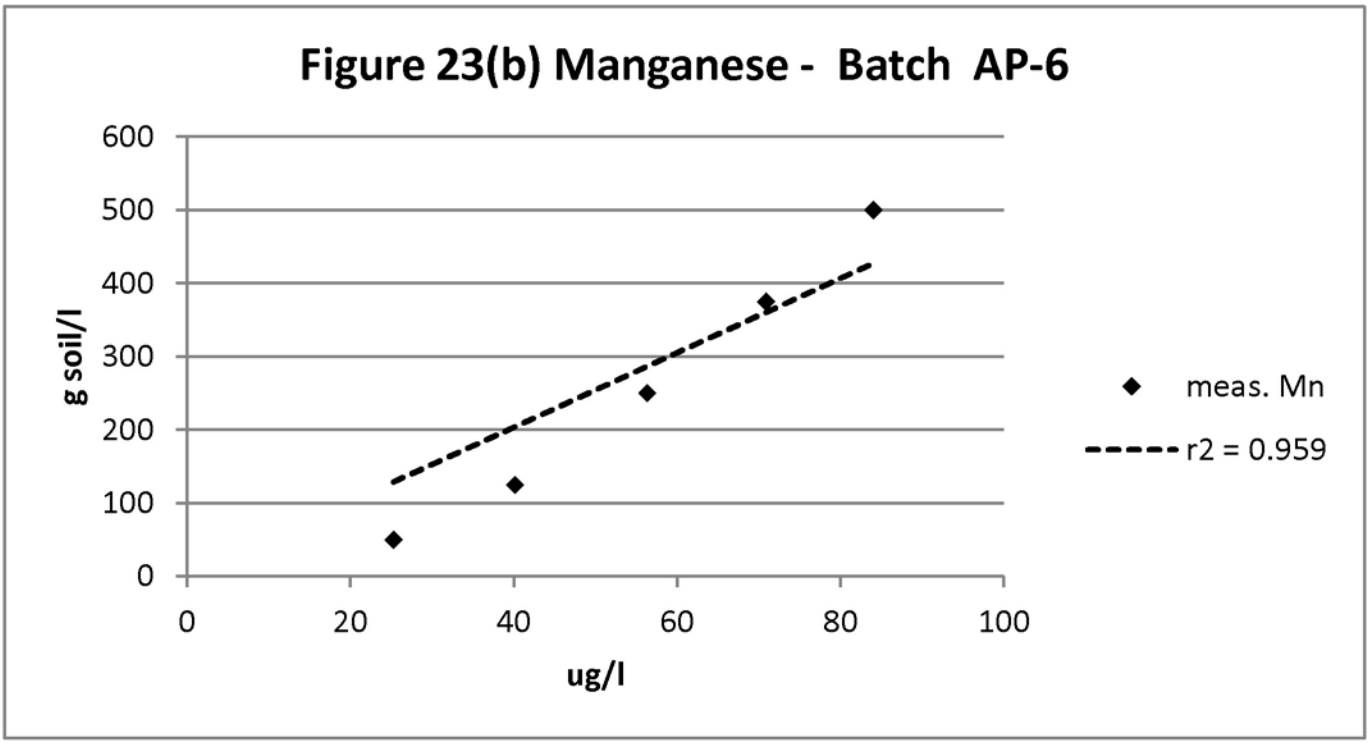


Figure 23(b) Manganese - Batch AP-6
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
100
ug/l
meas. Mn
r2 = 0.959

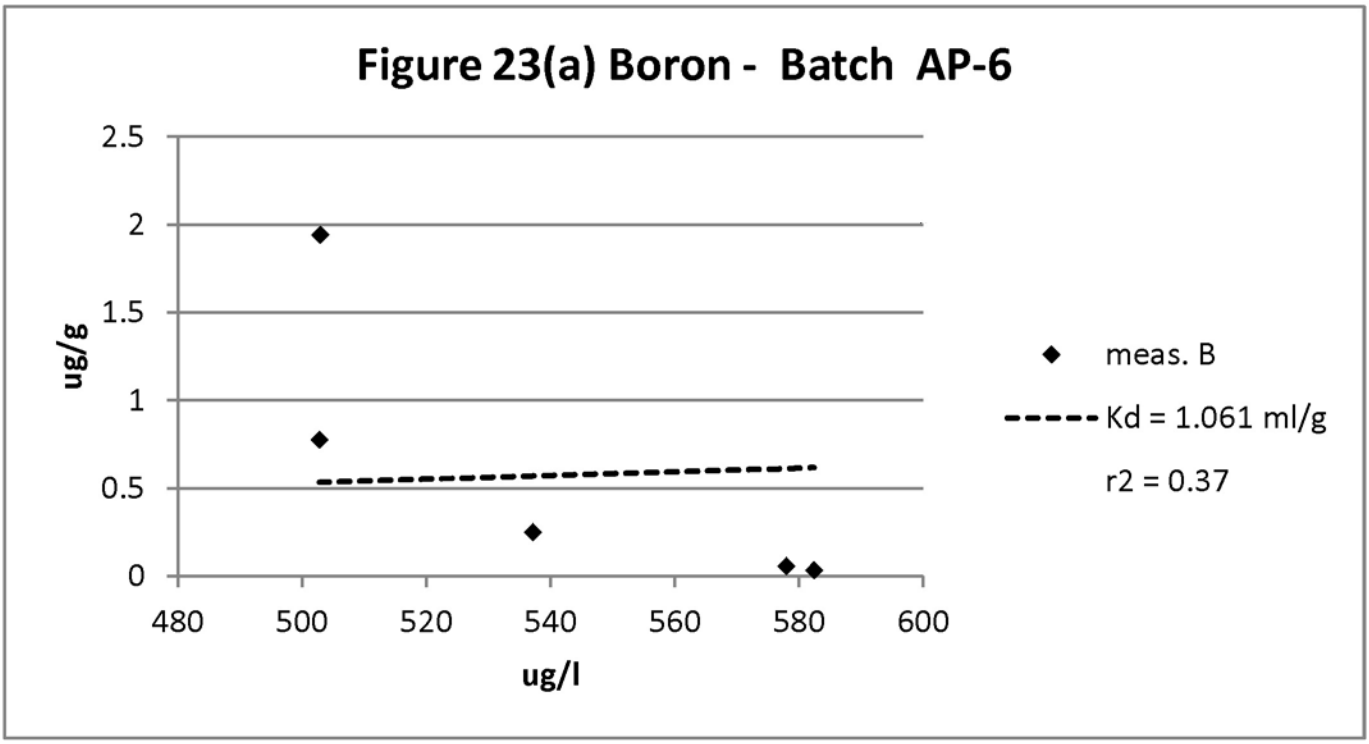


Figure 23(a) Boron - Batch AP-6
2.5
2
1.5
1
0.5
0
ug/g
480
500
520
540
560
580
600
ug/l
meas. B
Kd = 1.061 ml/g
r2 = 0.37

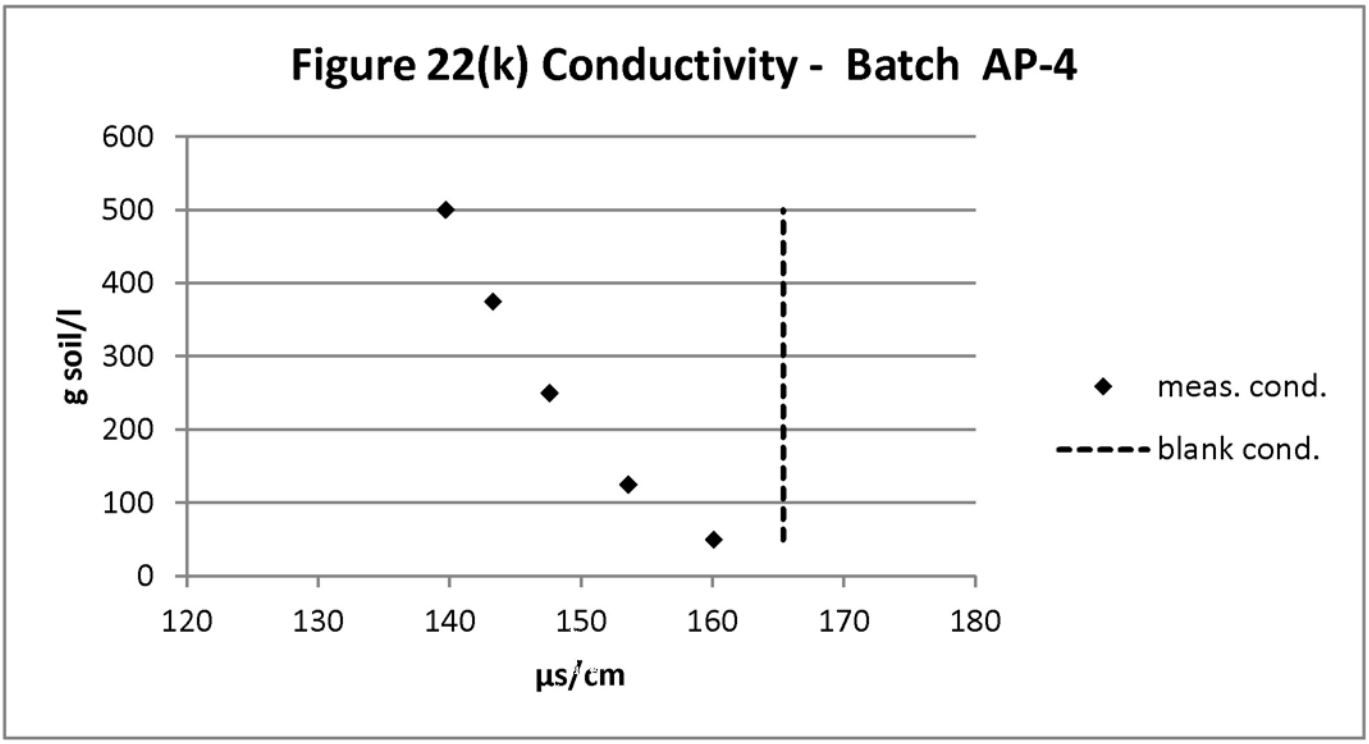


Figure 22(k) Conductivity - Batch AP-4
600
500
400
300
200
100
0
g soil/l
120
130
140
150
160
170
180
µs/cm
meas. cond.
blank cond.

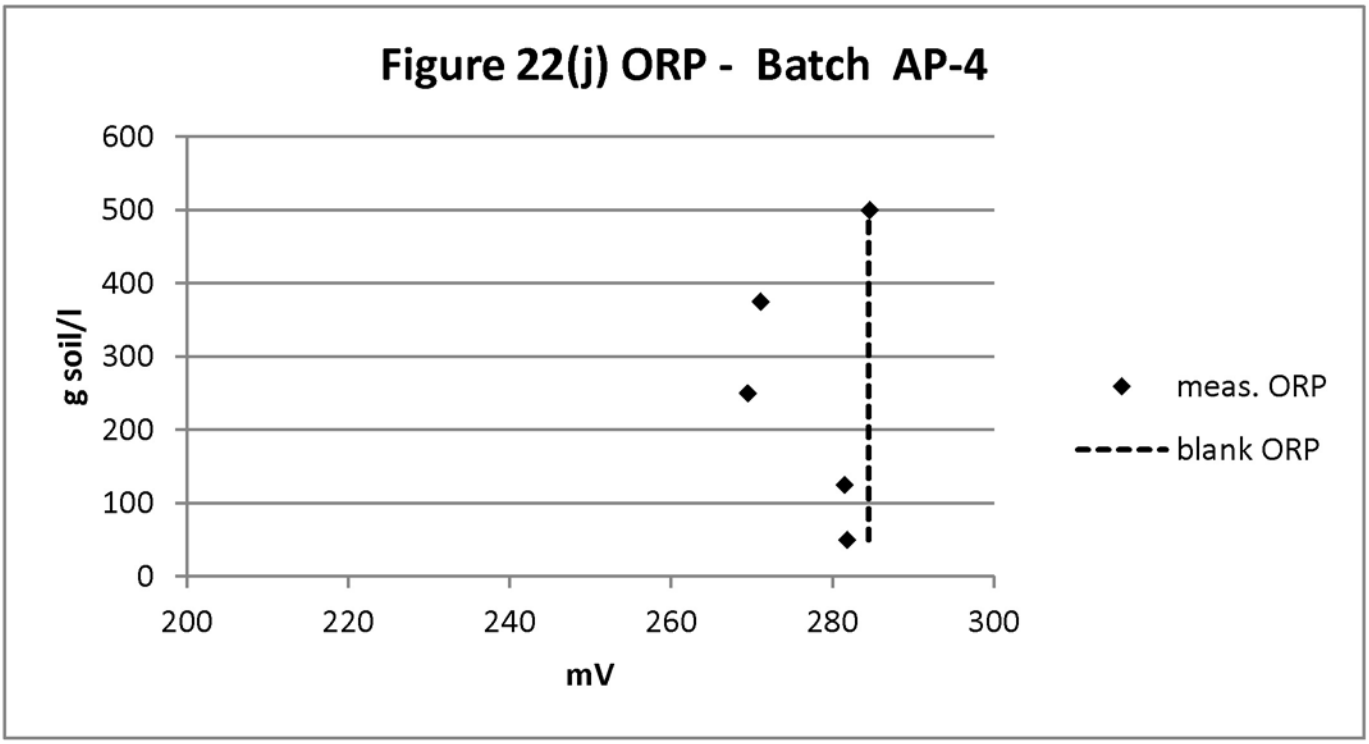


Figure 22(j) ORP - Batch AP-4
600
500
400
300
200
100
0
g soil/l
200
220
240
260
280
300
mV
meas. ORP
blank ORP

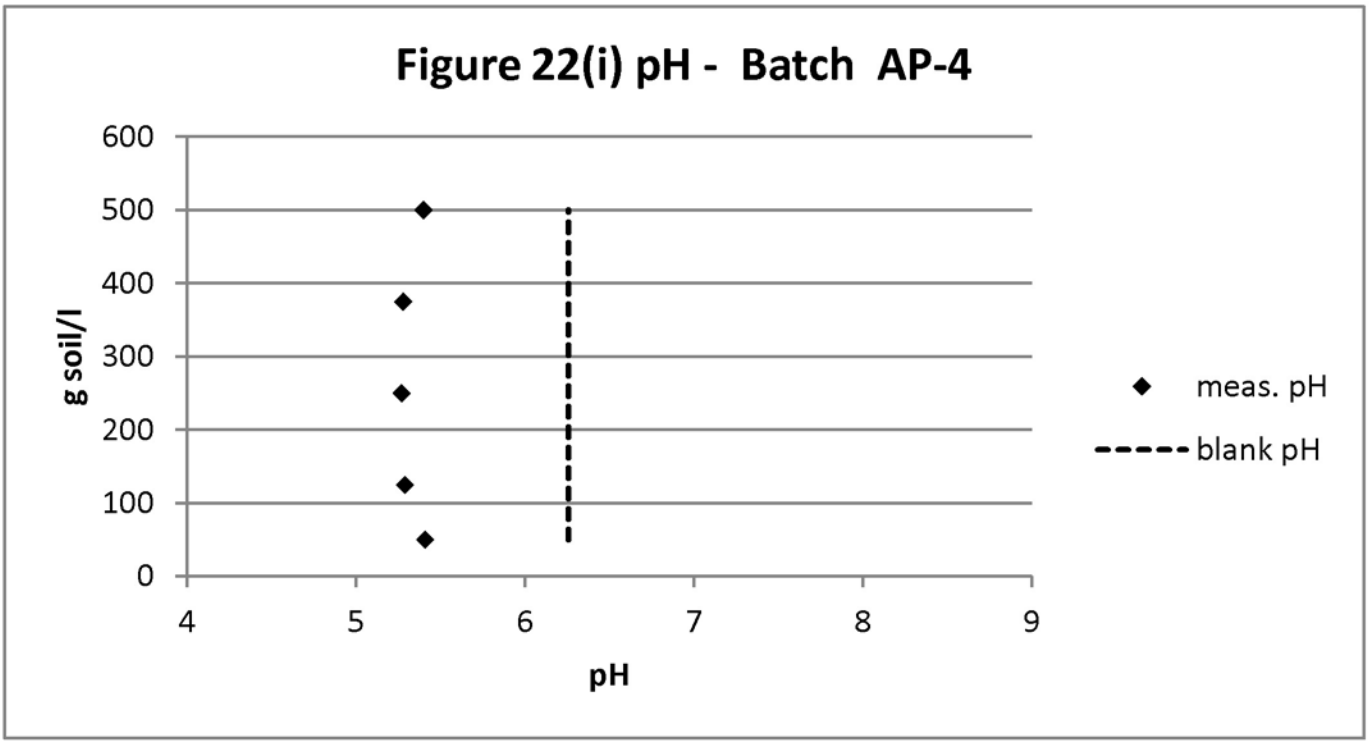


Figure 22(i) pH - Batch AP-4
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

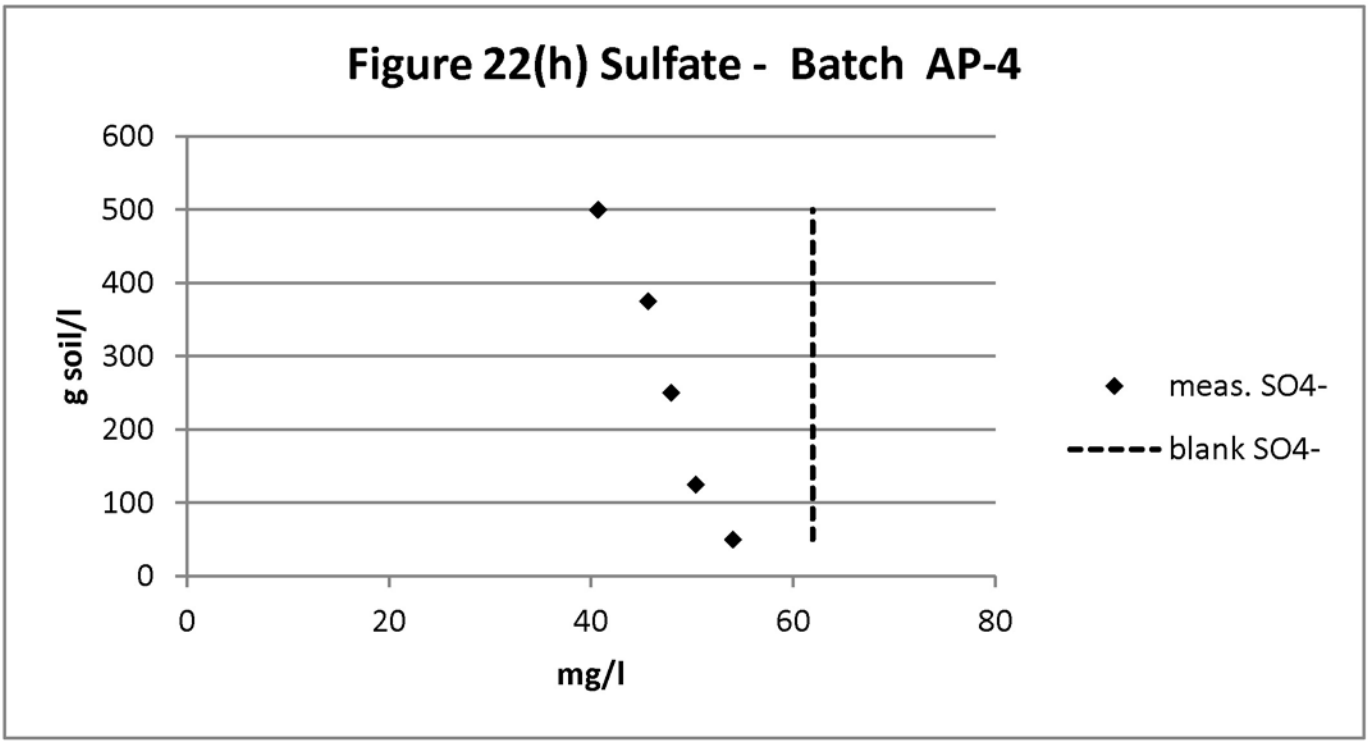


Figure 22(h) Sulfate - Batch AP-4
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

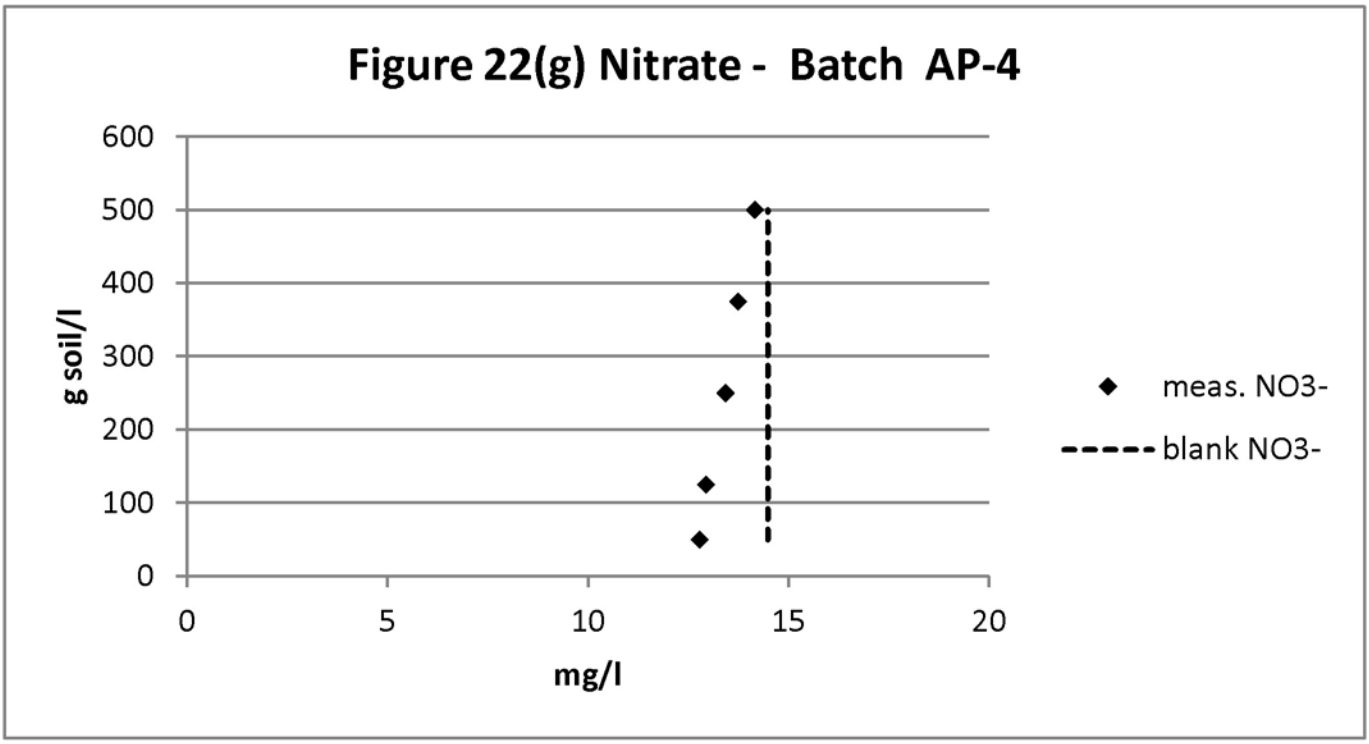


Figure 22(g) Nitrate - Batch AP-4
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

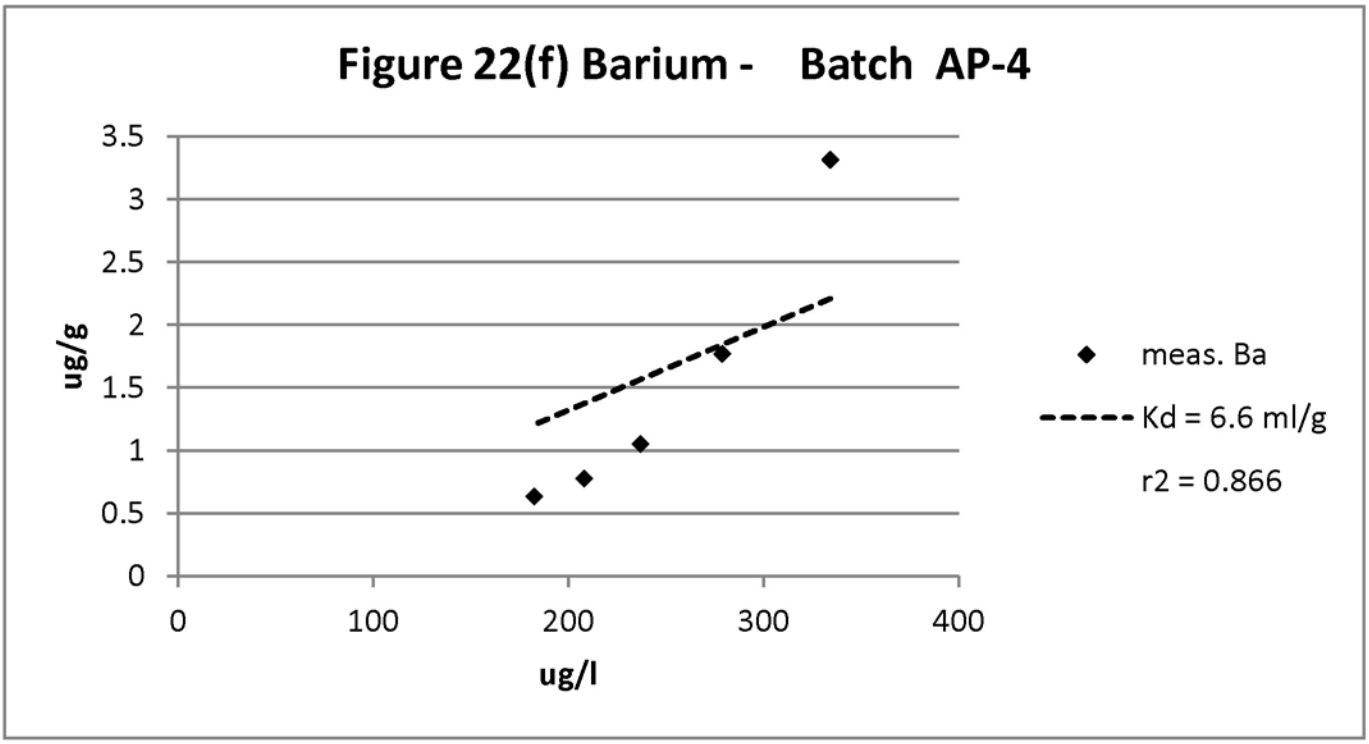


Figure 22(f) Barium - Batch AP-4
3.5
3
2.5
2
1.5
1
0.5
0
ug/g
0
100
200
300
400
ug/l
meas. Ba
Kd = 6.6 ml/g
r2 = 0.866

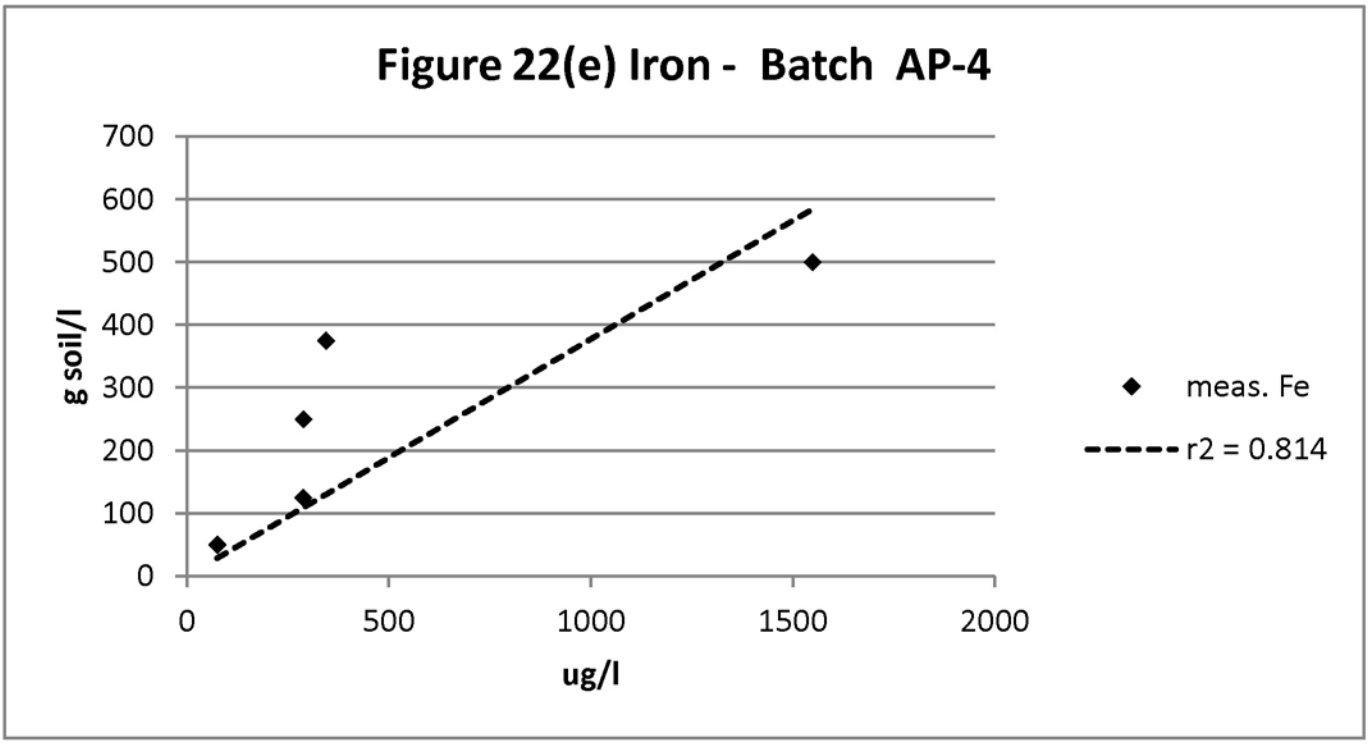


Figure 22(e) Iron - Batch AP-4
700
600
500
400
300
200
100
0
g soil/l
0
500
1000
1500
2000
ug/l
meas. Fe
r2 = 0.814

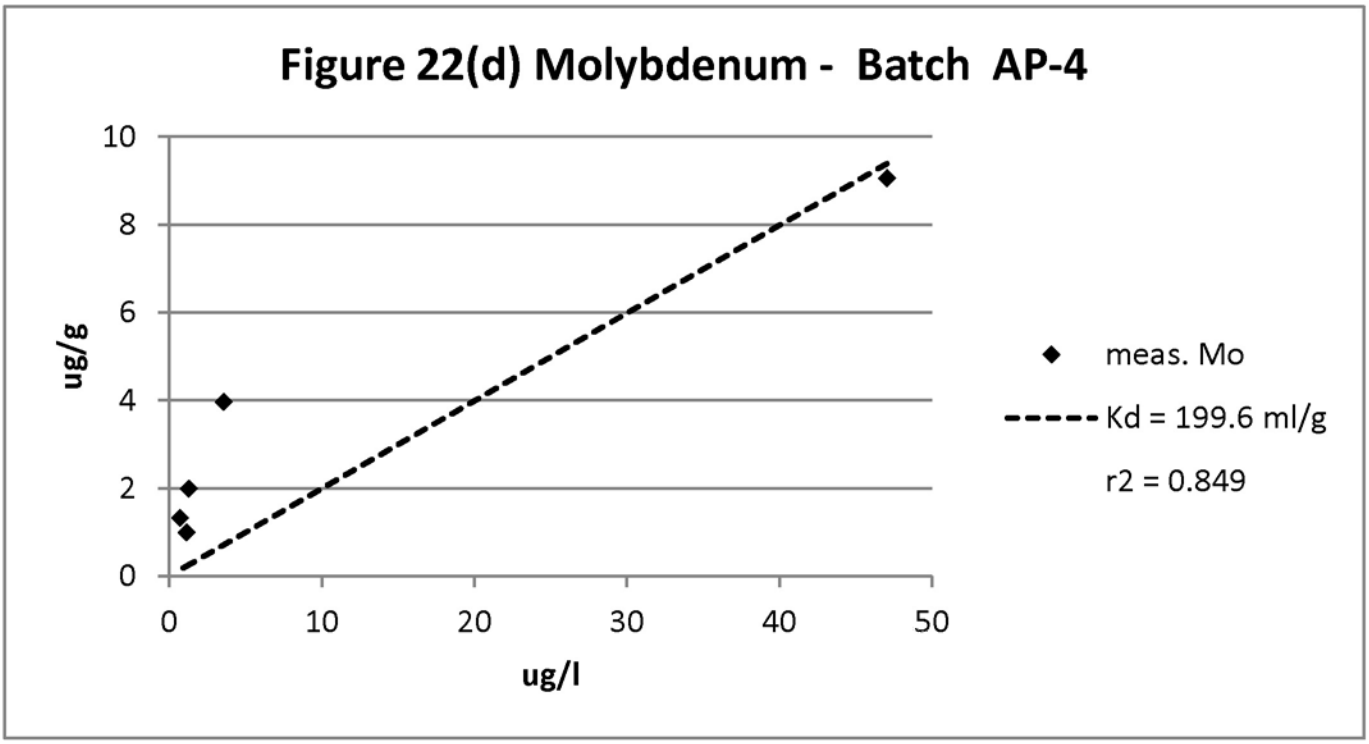


Figure 22(d) Molybdenum - Batch AP-4
10
8
6
4
2
0
ug/g
0
10
20
30
40
50
ug/l
meas. Mo
Kd = 199.6 ml/g
r2 = 0.849

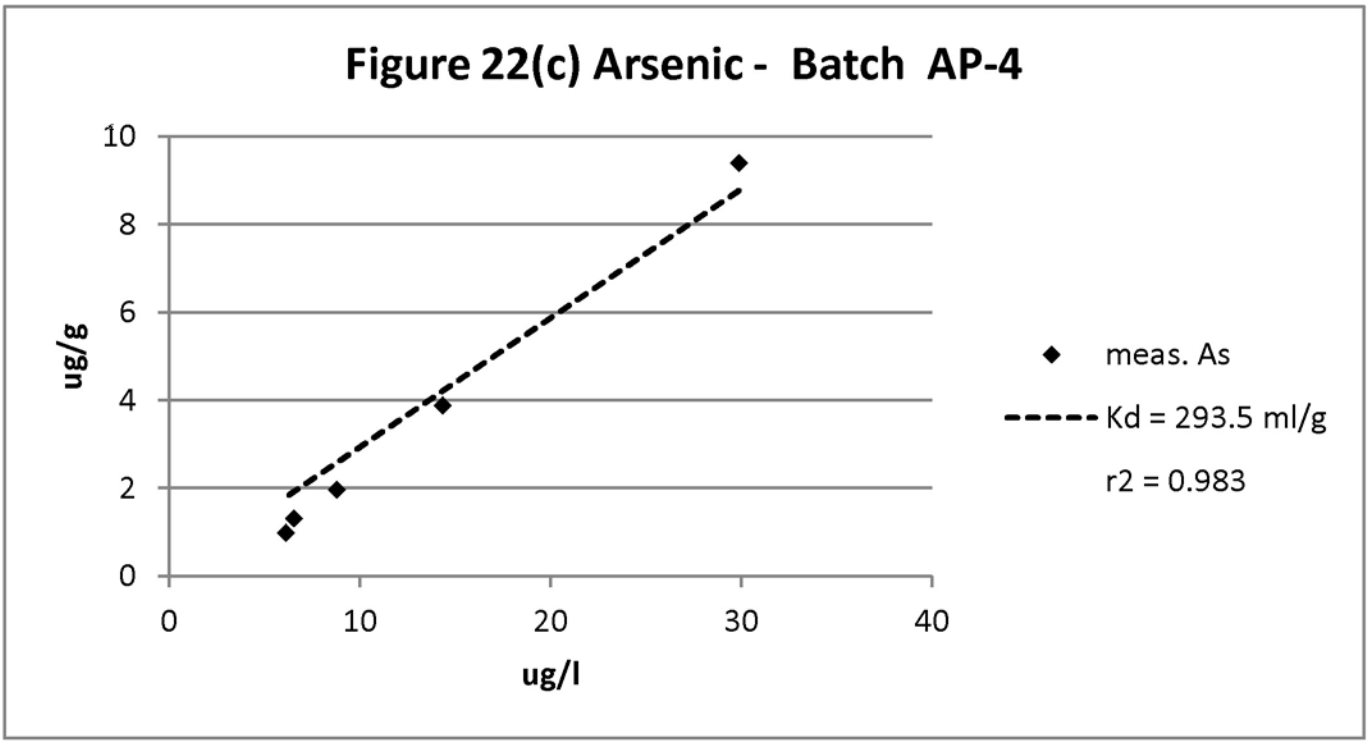


Figure 22(c) Arsenic - Batch AP-4
10
8
6
4
2
0
ug/g
0
10
20
30
40
ug/l
meas. As
Kd = 293.5 ml/g
r2 = 0.983

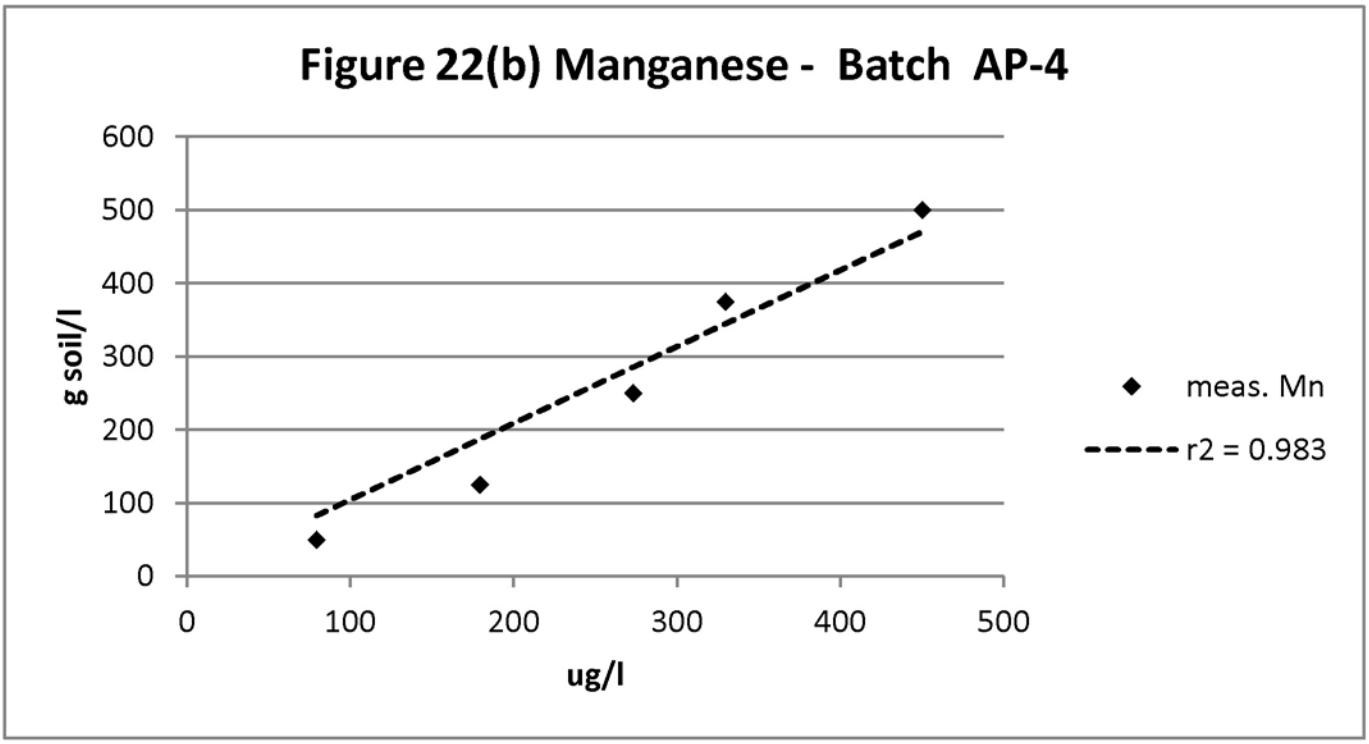


Figure 22(b) Manganese - Batch AP-4
600
500
400
300
200
100
0
g soil/l
0
100
200
300
400
500
ug/l
meas. Mn
r2 = 0.983

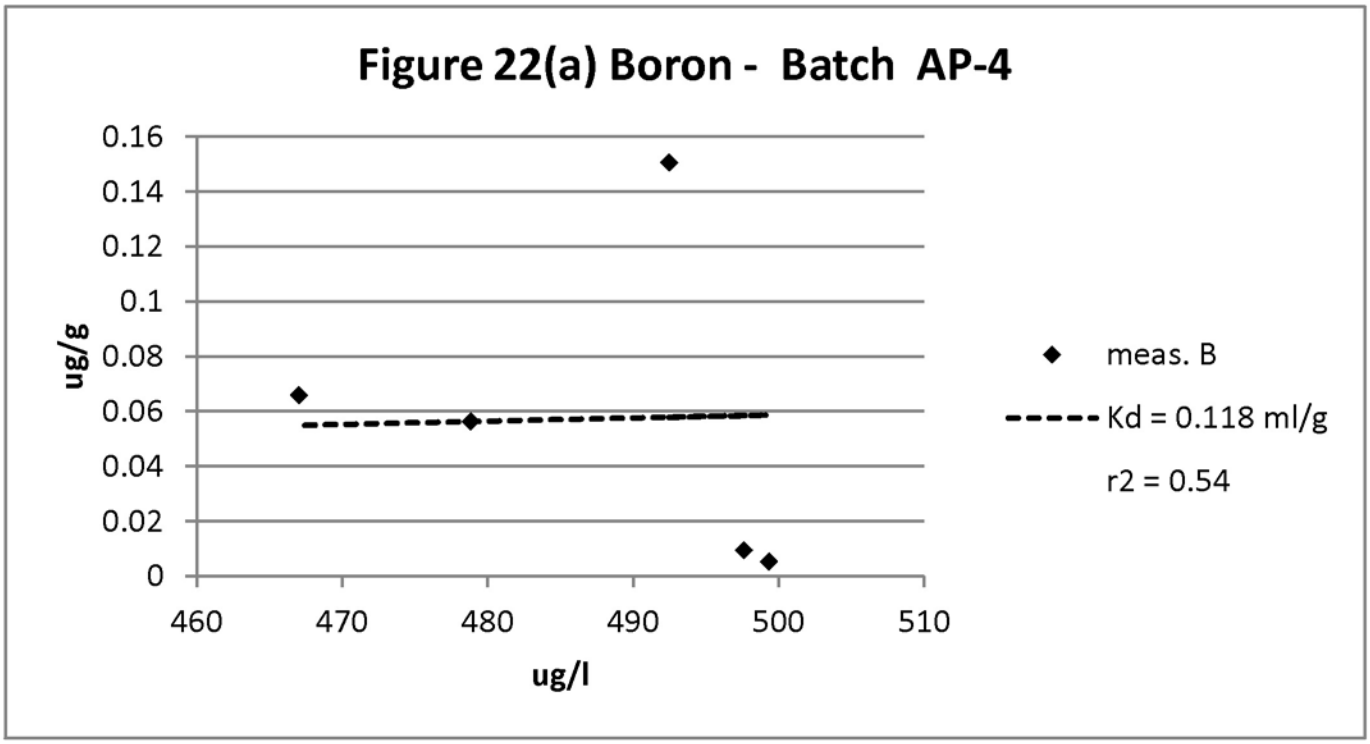


Figure 22(a) Boron - Batch AP-4
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
ug/g
460
470
480
490
500
510
ug/l
meas. B
Kd = 0.118 ml/g
r2 = 0.54

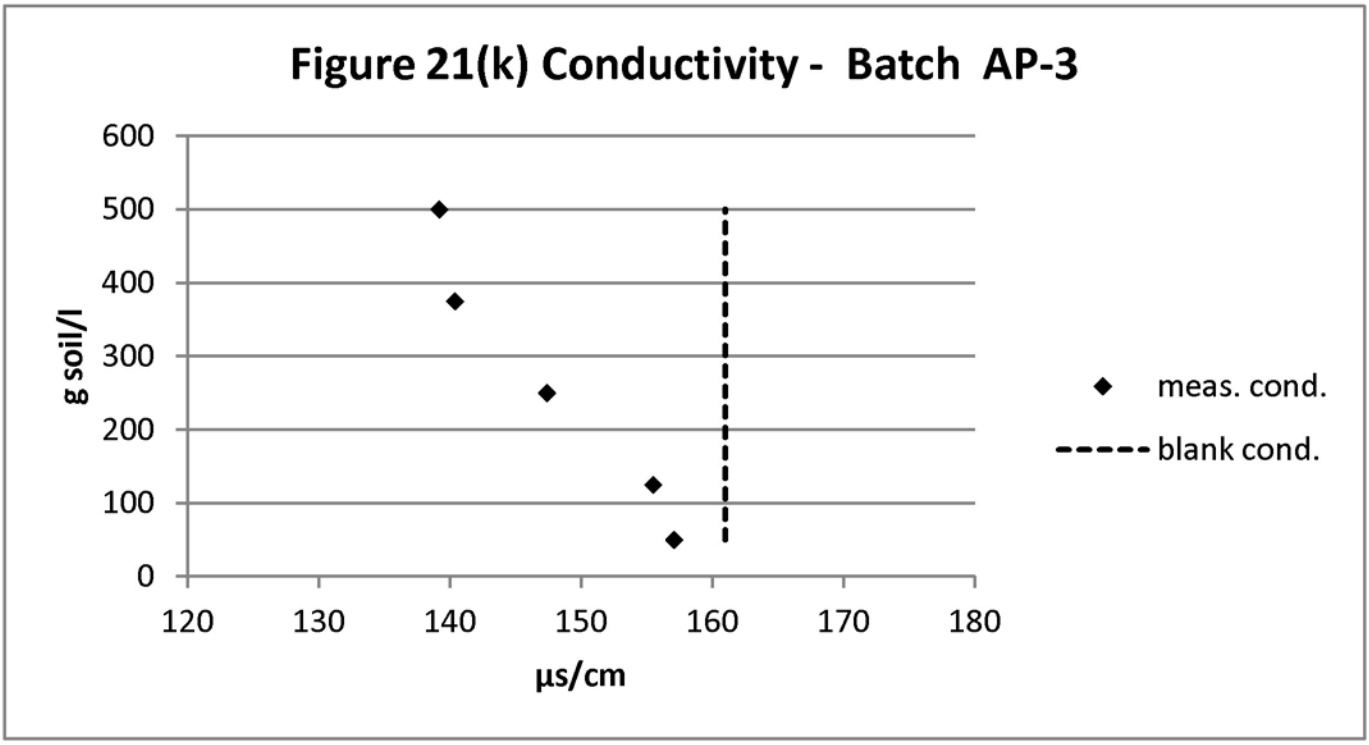


Figure 21(k) Conductivity - Batch AP-3
600
500
400
300
200
100
0
g soil/l
120
130
140
150
160
170
180
µs/cm
meas. cond.
blank cond.

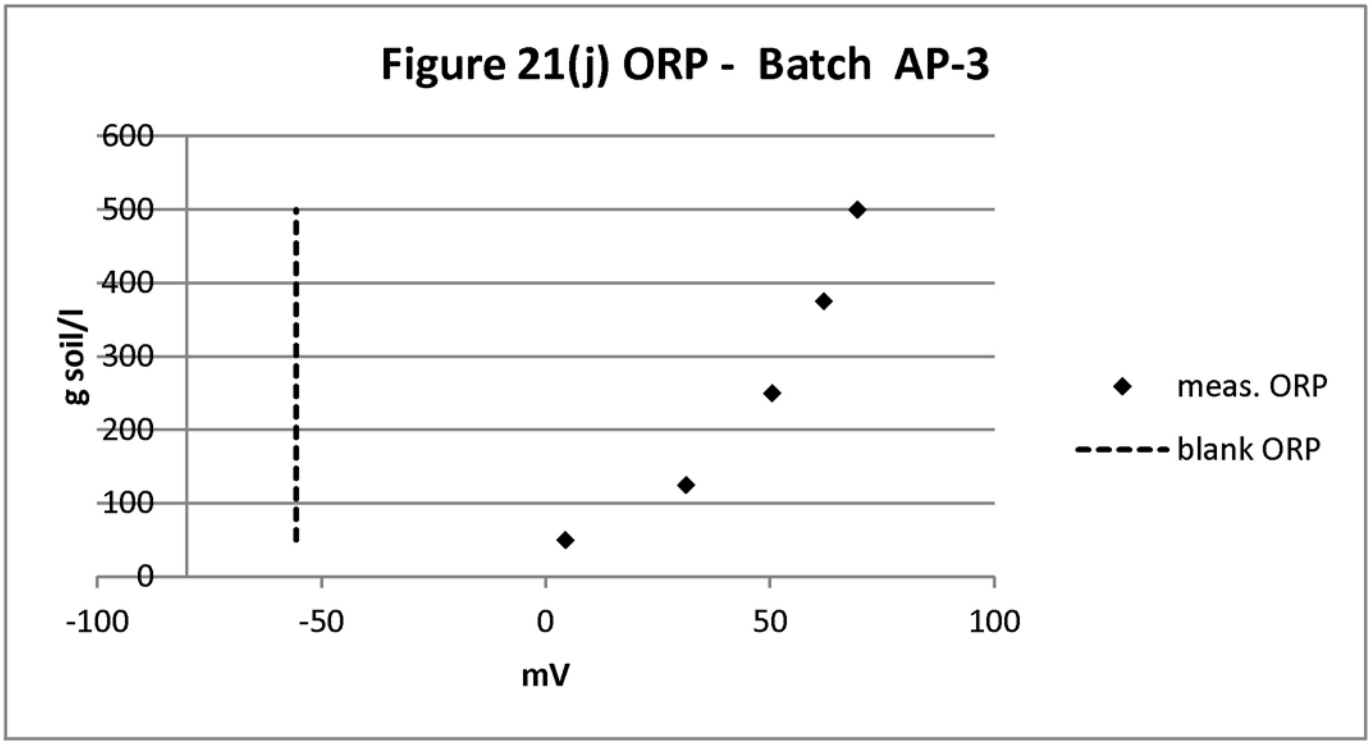


Figure 21(j) ORP - Batch AP-3
600
500
400
300
200
100
0
g soil/l
-100
-50
0
50
100
mV
meas. ORP
blank ORP

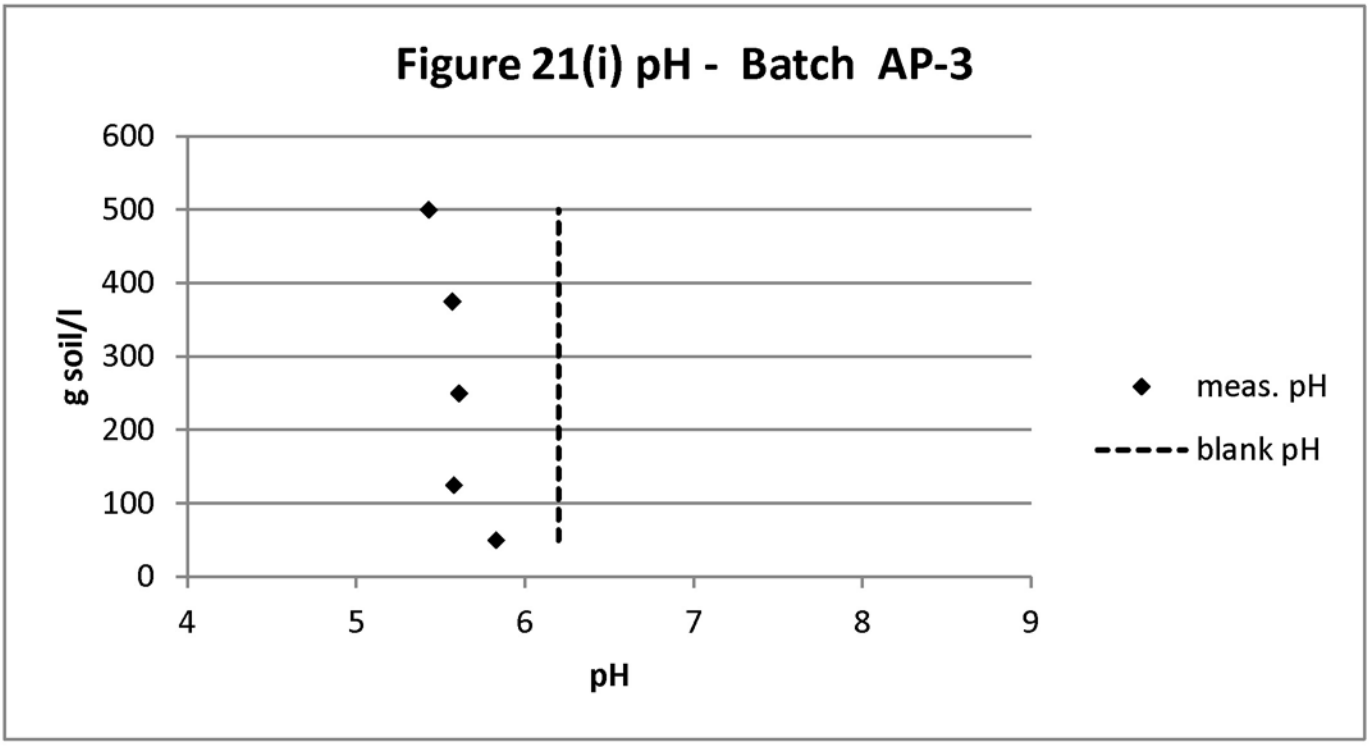


Figure 21(i) pH - Batch AP-3
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

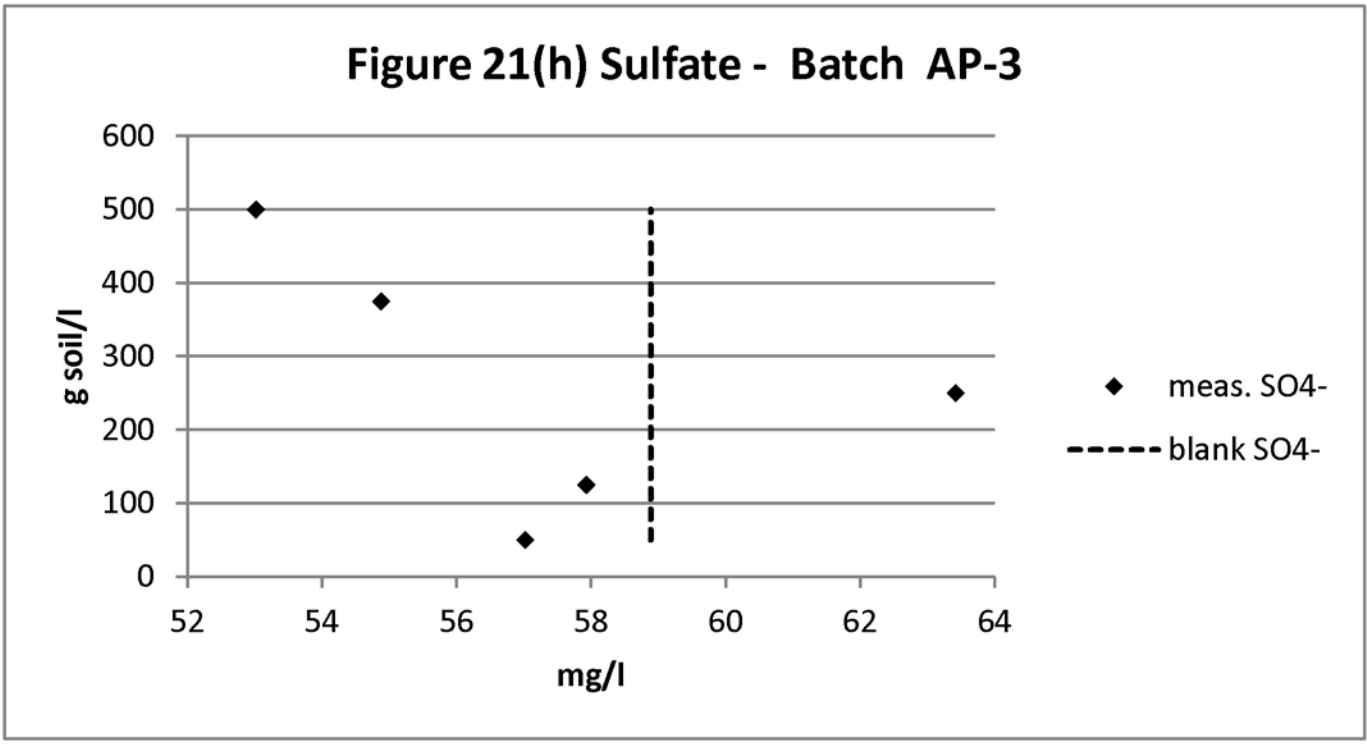


Figure 21(h) Sulfate - Batch AP-3
600
500
400
300
200
100
0
g soil/l
52
54
56
58
60
62
64
mg/l
meas. SO4-
blank SO4-

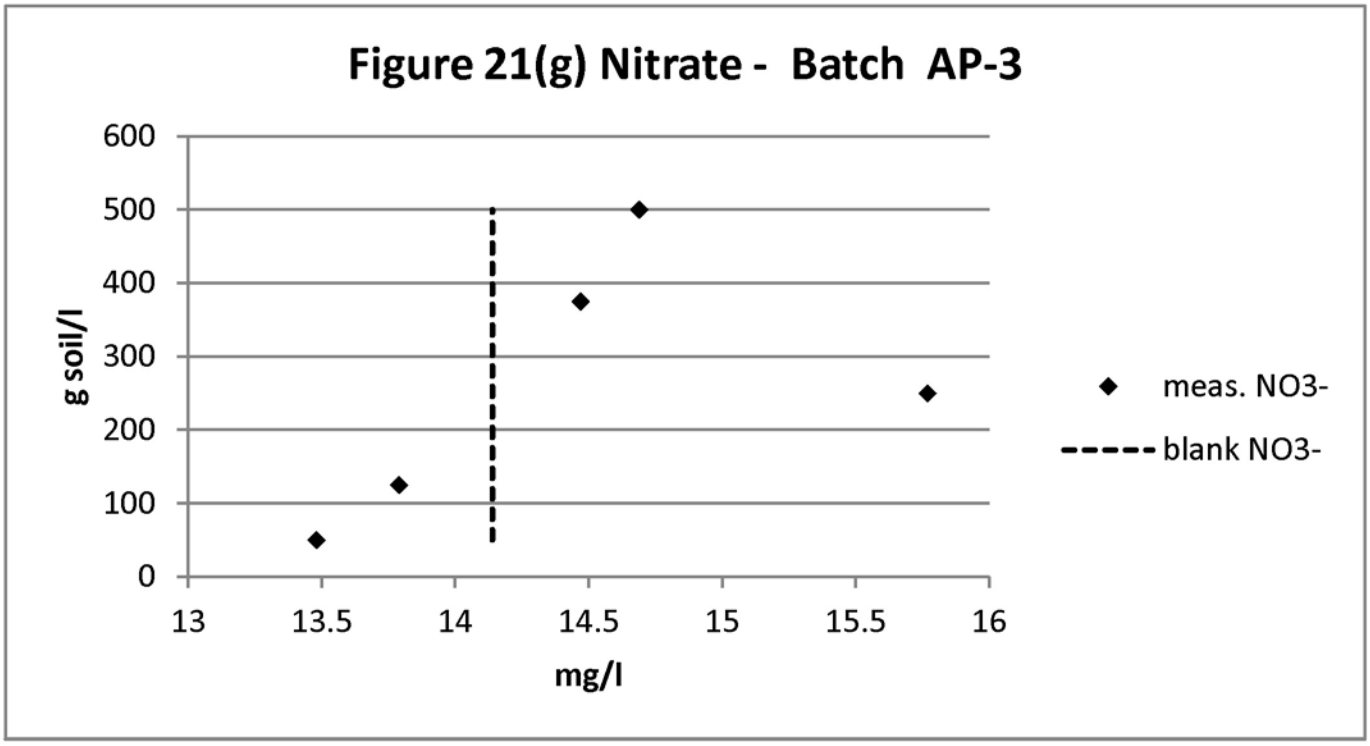


Figure 21(g) Nitrate - Batch AP-3
600
500
400
300
200
100
0
g soil/l
13
13.5
14
14.5
15
15.5
16
mg/l
meas. NO3-
blank NO3-

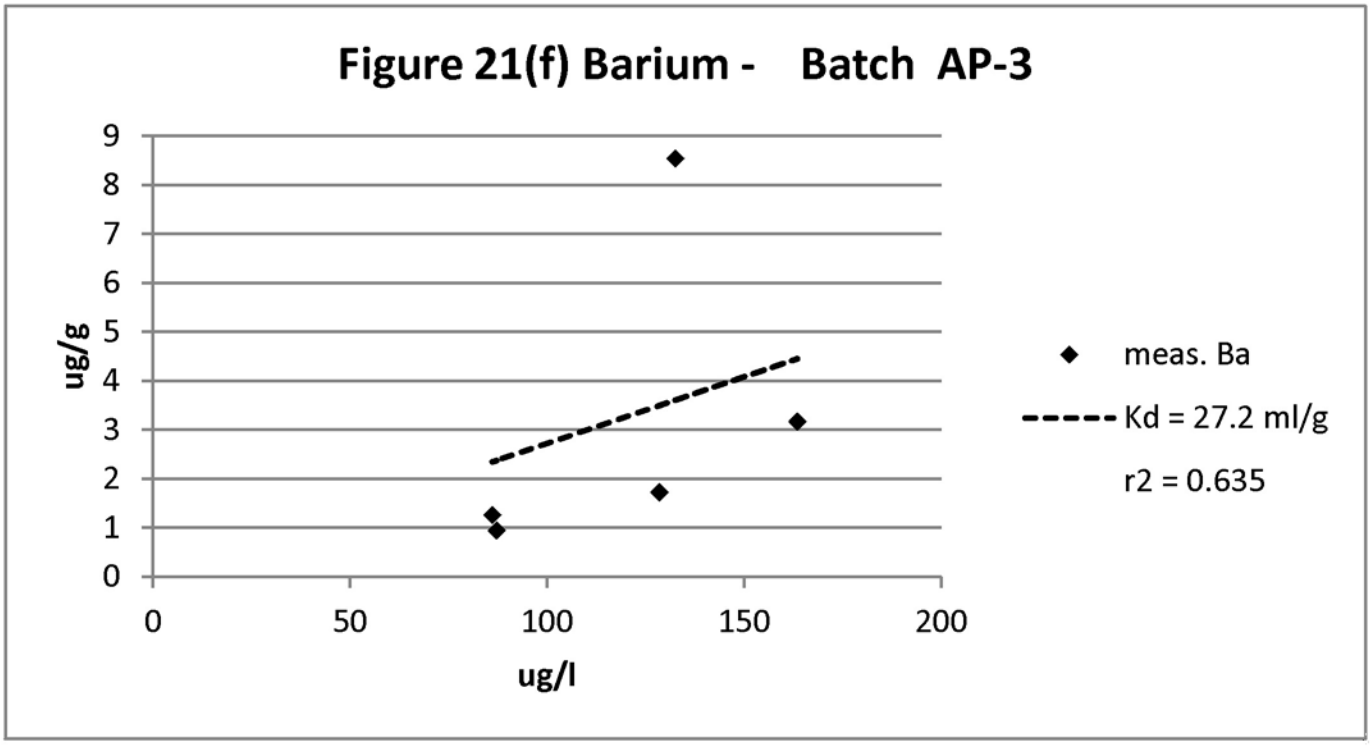


Figure 21(f) Barium - Batch AP-3
9
8
7
6
5
4
3
2
1
0
ug/g
0
50
100
150
200
ug/l
meas. Ba
Kd = 27.2 ml/g
r2 = 0.635

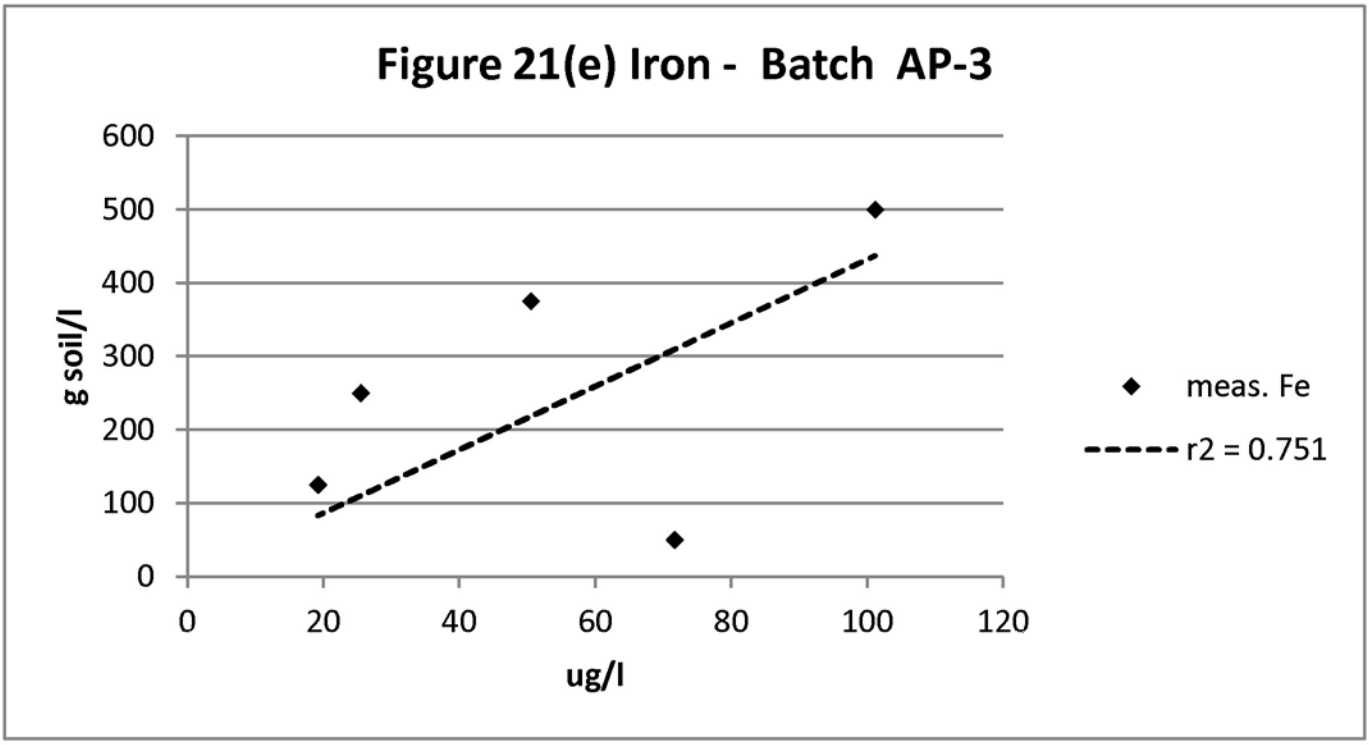


Figure 21(e) Iron - Batch AP-3
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
100
120
ug/l
meas. Fe
r2 = 0.751

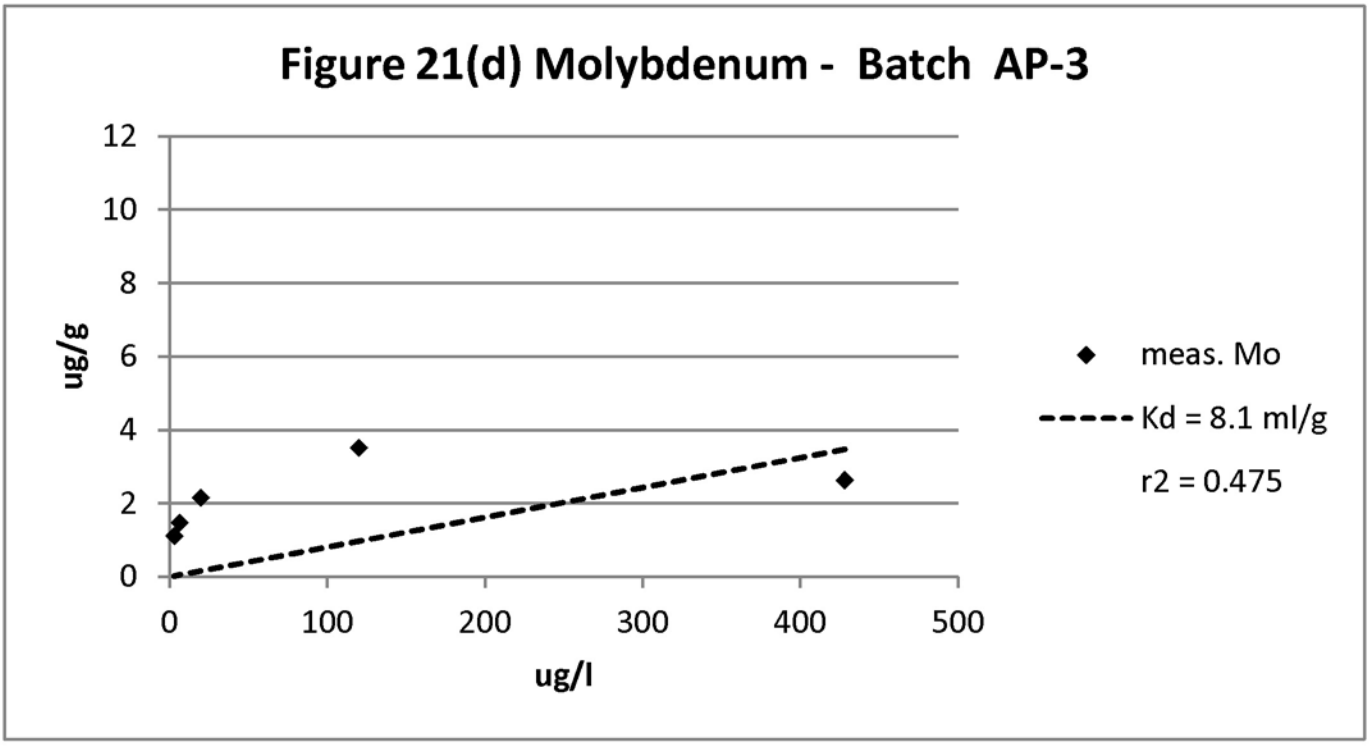


Figure 21(d) Molybdenum - Batch AP-3
12
10
8
6
4
2
0
ug/g
0
100
200
300
400
500
ug/l
meas. Mo
Kd = 8.1 ml/g
r2 = 0.475

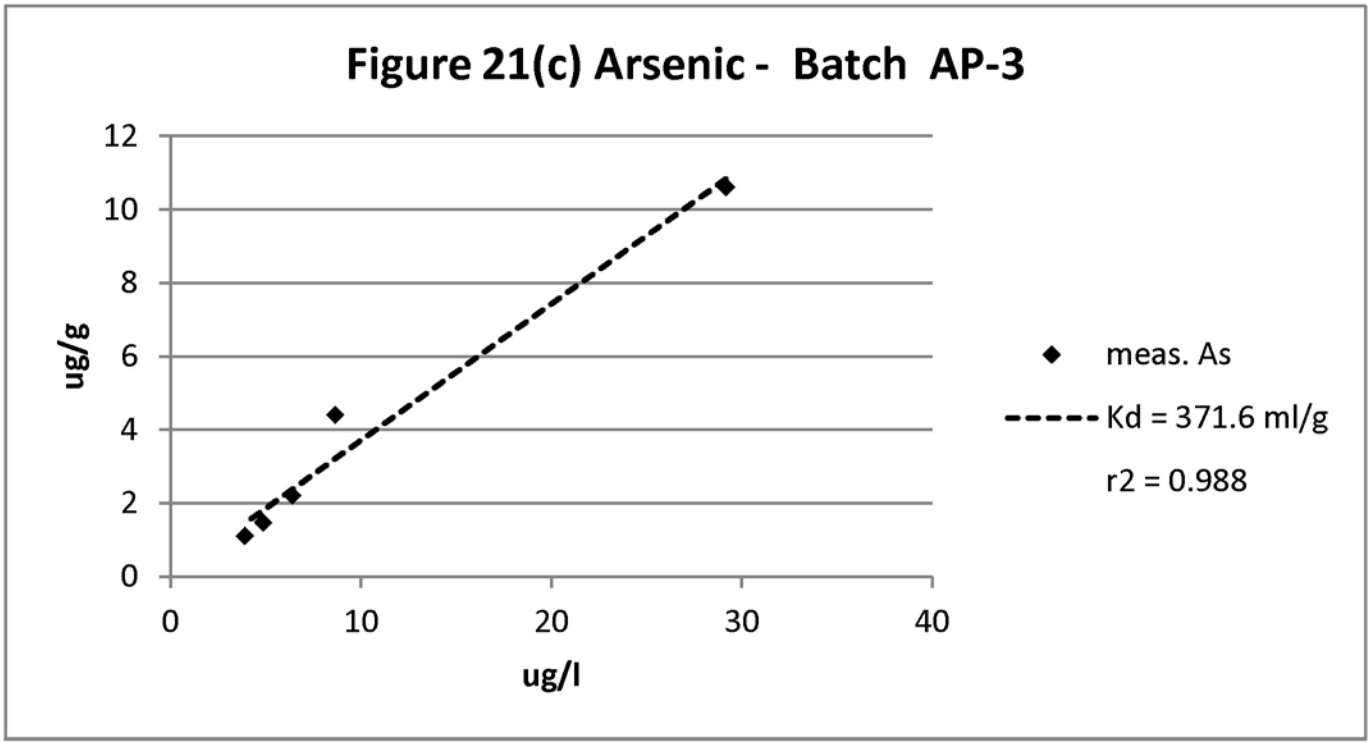


Figure 21(c) Arsenic - Batch AP-3
12
10
8
6
4
2
0
ug/g
0
10
20
30
40
ug/l
meas. As
Kd = 371.6 ml/g
r2 = 0.988

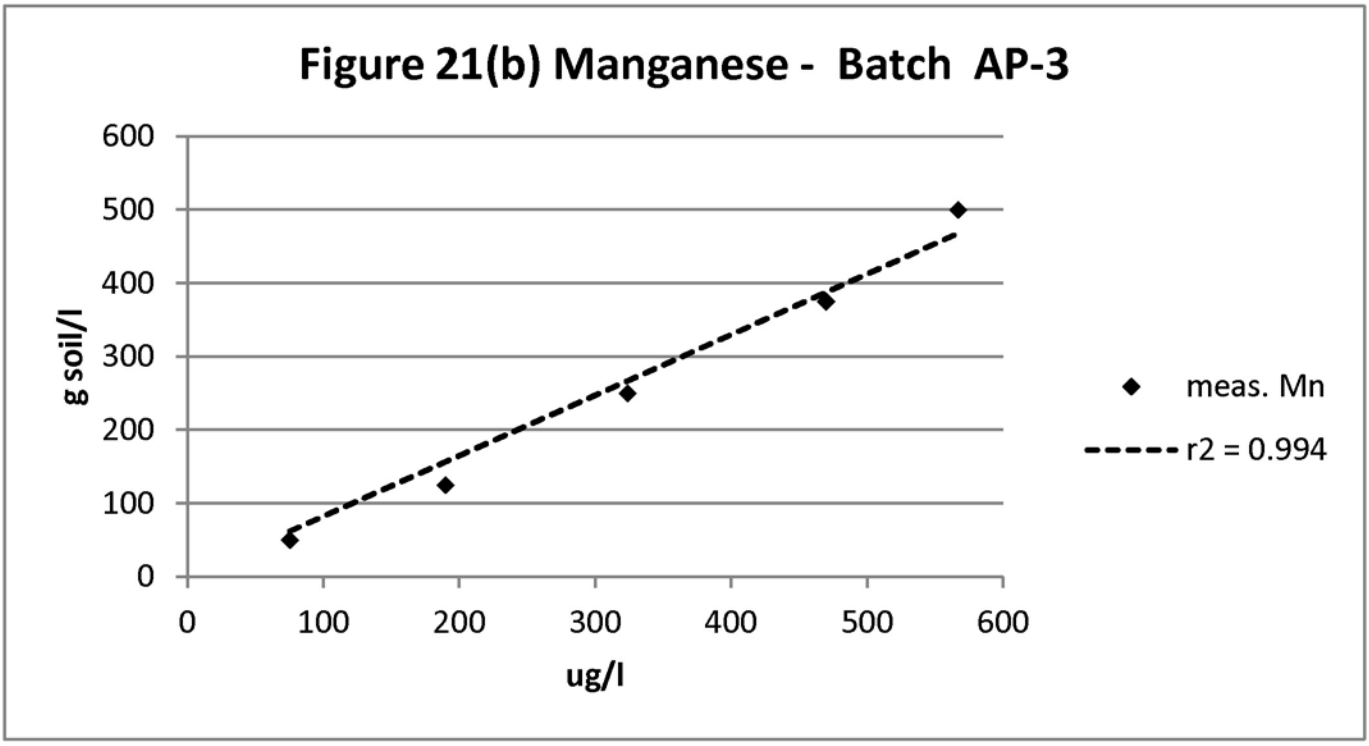


Figure 21(b) Manganese - Batch AP-3
600
500
400
300
200
100
0
g soil/l
0
100
200
300
400
500
600
ug/l
meas. Mn
r2 = 0.994

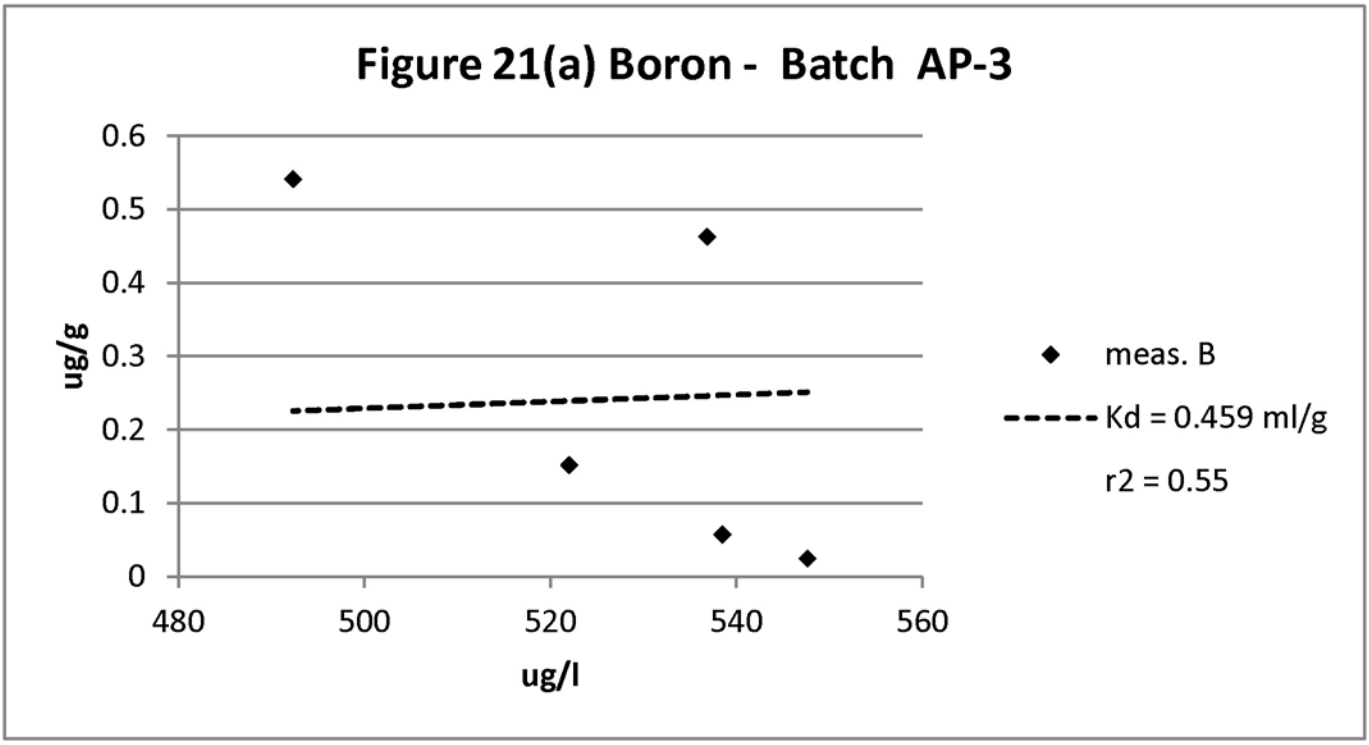


Figure 21(a) Boron - Batch AP-3
0.6
0.5
0.4
0.3
0.2
0.1
0
ug/g
480
500
520
540
560
ug/l
meas. B
Kd = 0.459 ml/g
r2 = 0.55

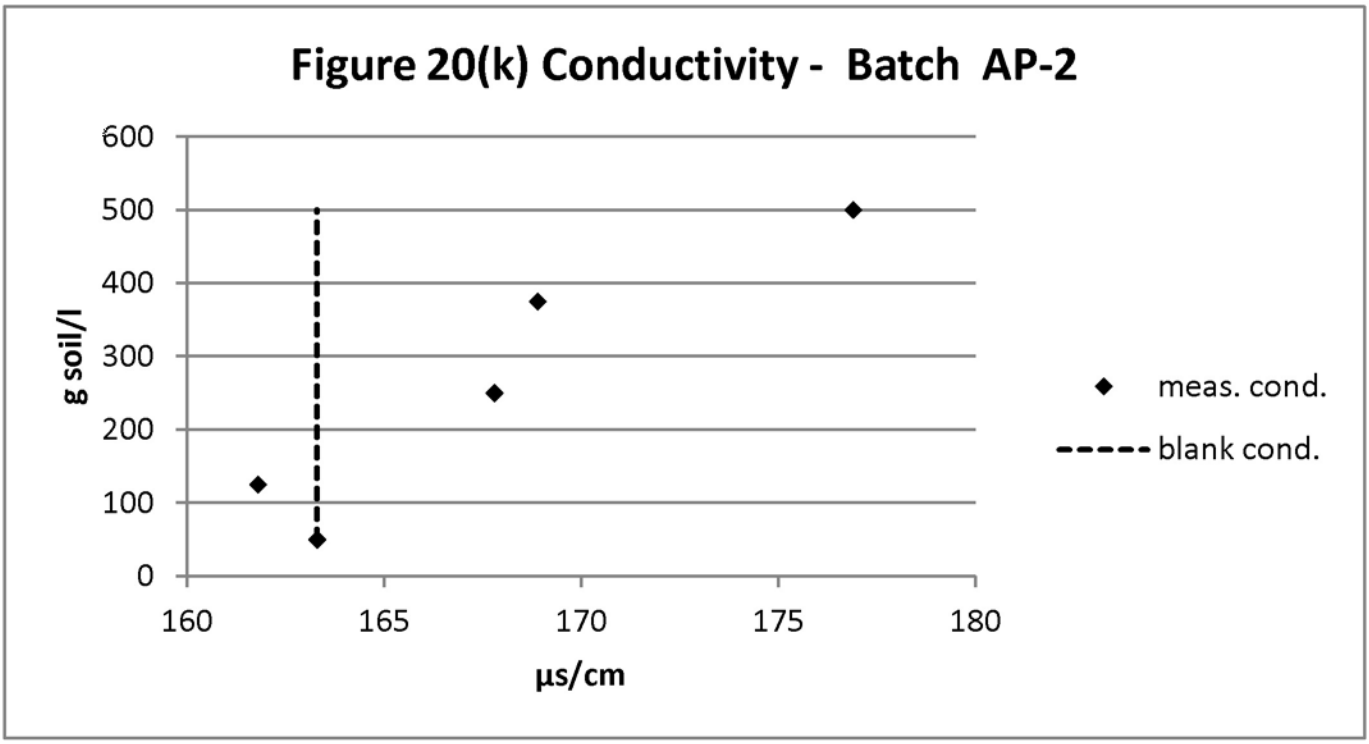


Figure 20(k) Conductivity - Batch AP-2
600
500
400
300
200
100
0
g soil/l
160
165
170
175
180
µs/cm
meas. cond.
blank cond.

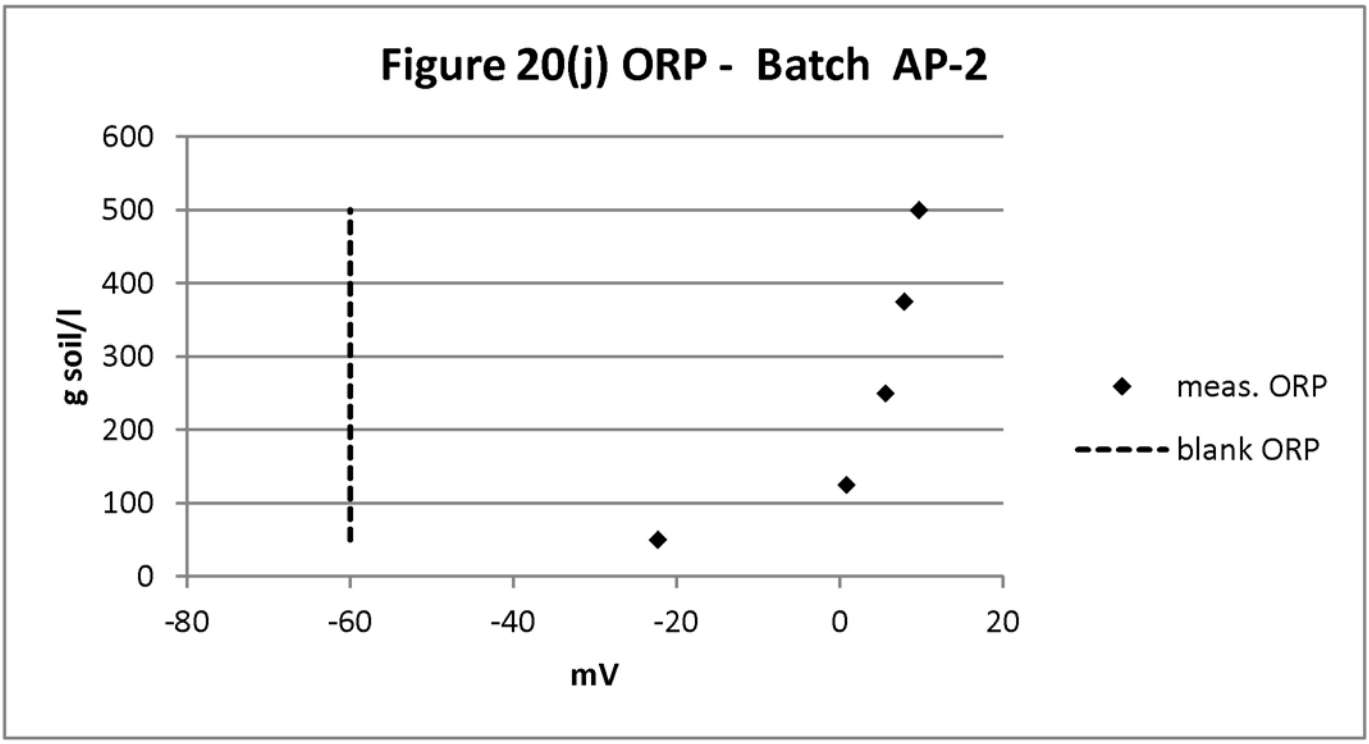


Figure 20(j) ORP - Batch AP-2
600
500
400
300
200
100
0
g soil/l
-80
-60
-40
-20
0
20
mV
meas. ORP
blank ORP

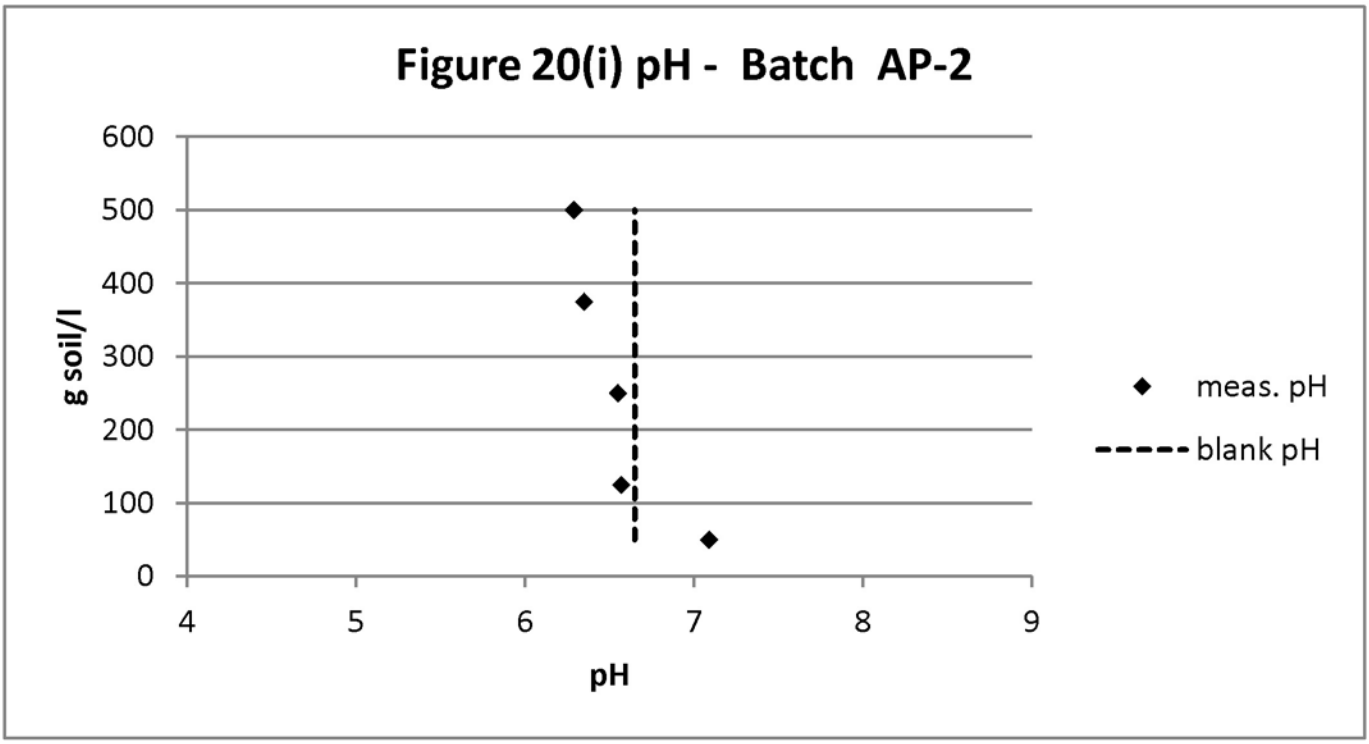


Figure 20(i) pH - Batch AP-2
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

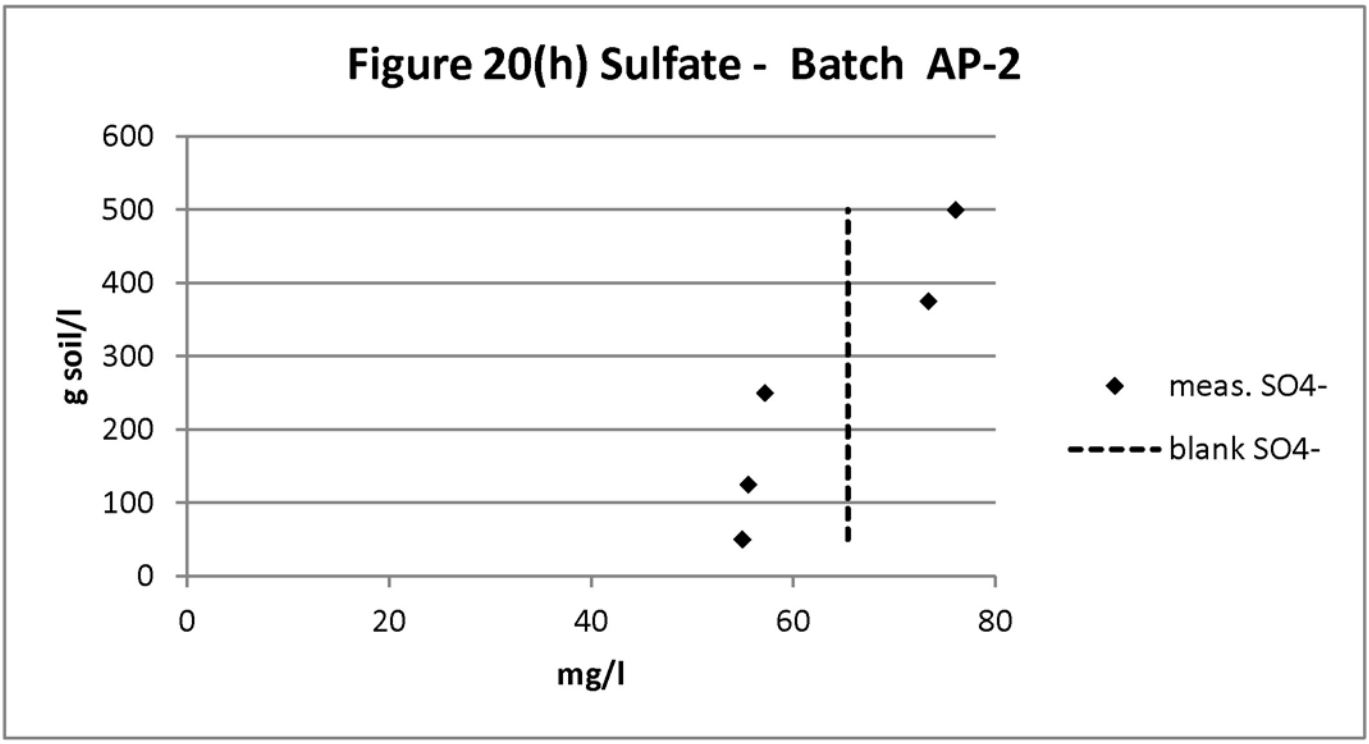


Figure 20(h) Sulfate - Batch AP-2
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

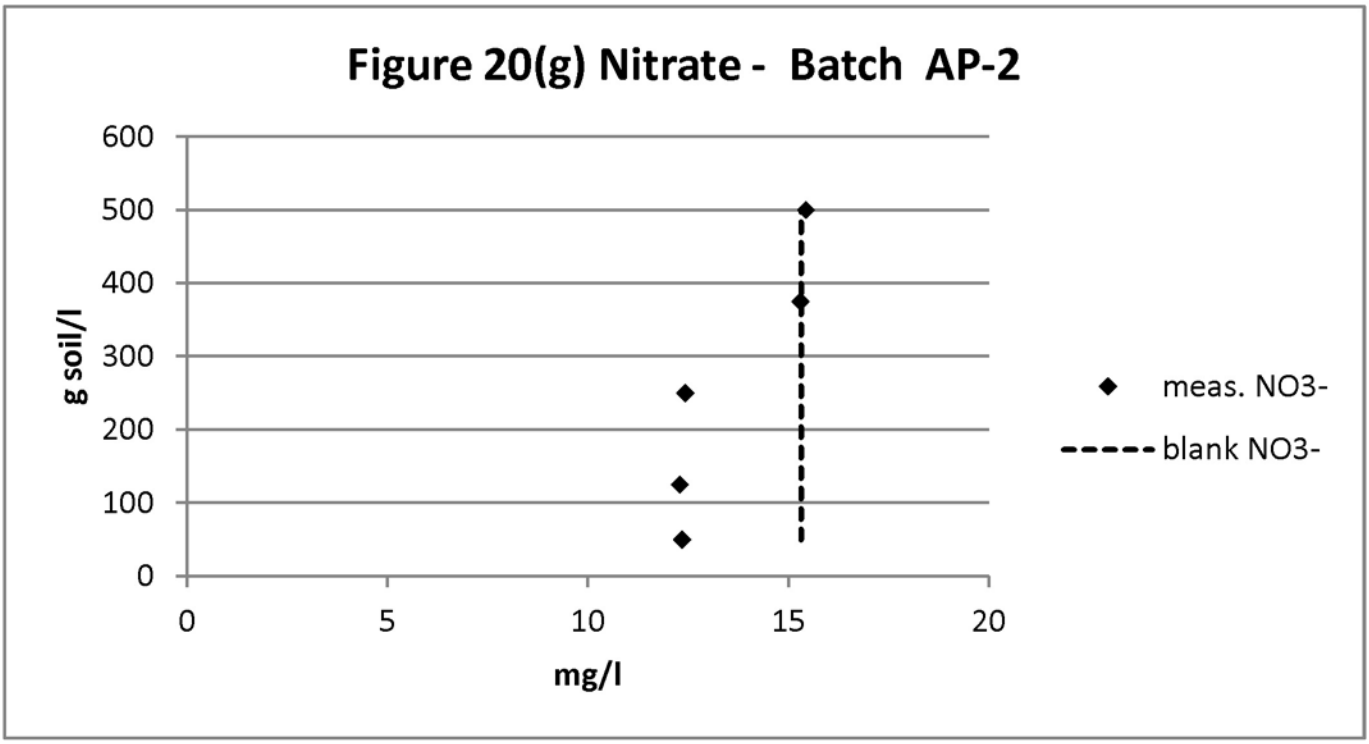


Figure 20(g) Nitrate - Batch AP-2
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

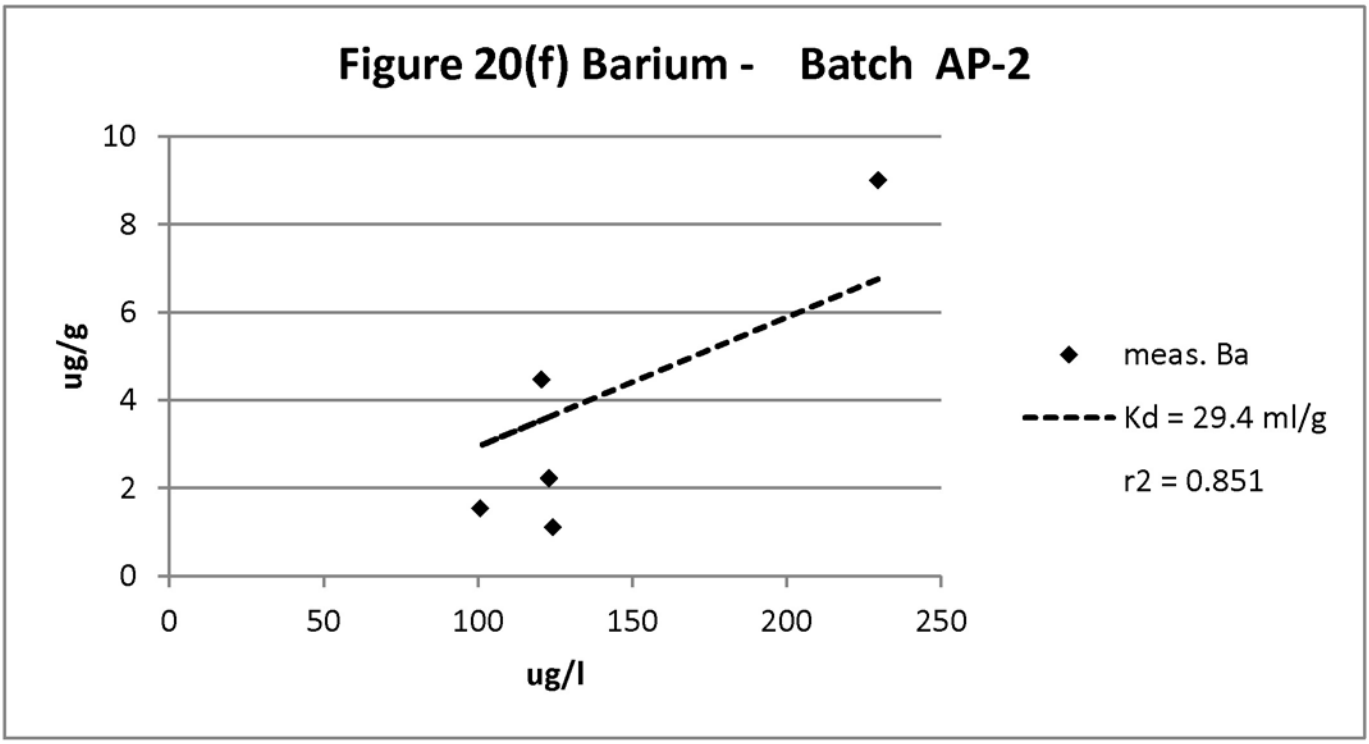


Figure 20(f) Barium - Batch AP-2
10
8
6
4
2
0
ug/g
0
50
100
150
200
250
ug/l
meas. Ba
Kd = 29.4 ml/g
r2 = 0.851

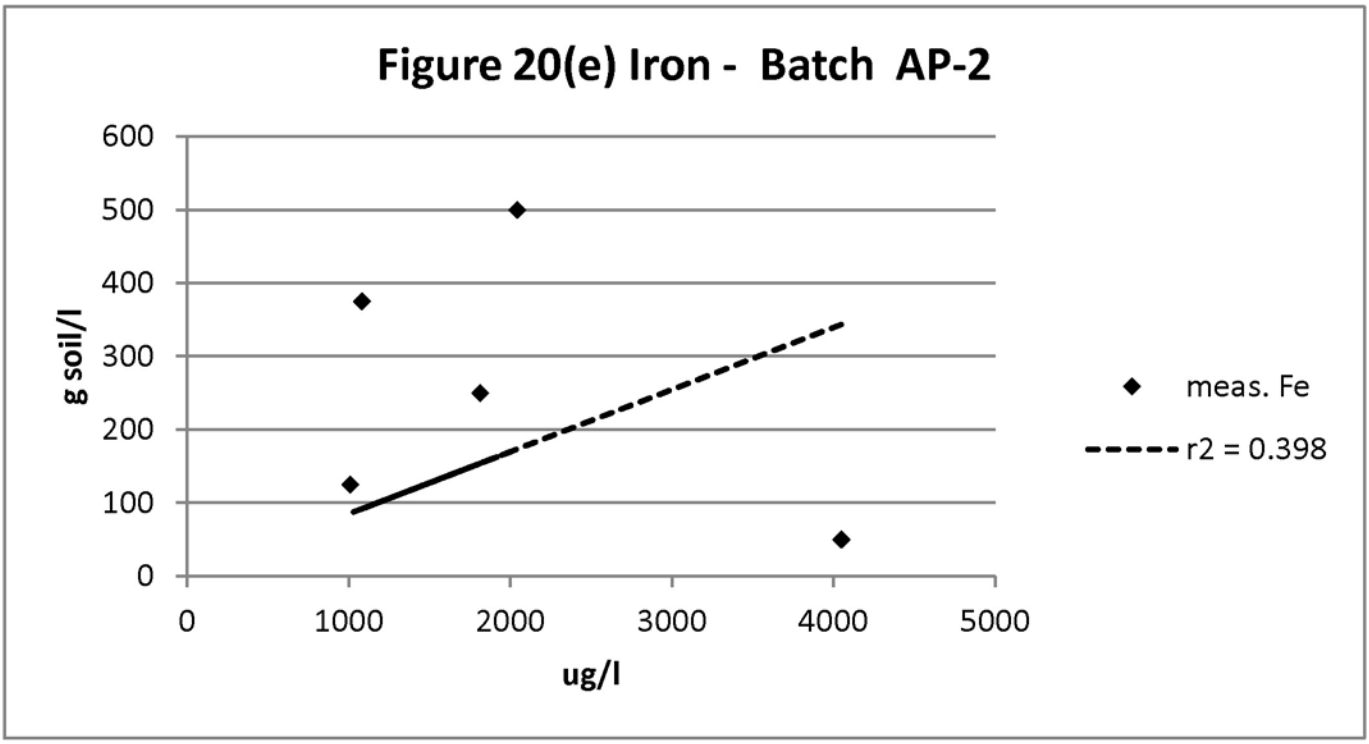


Figure 20(e) Iron - Batch AP-2
600
500
400
300
200
100
0
g soil/l
0
1000
2000
3000
4000
5000
ug/l
meas. Fe
r2 = 0.398

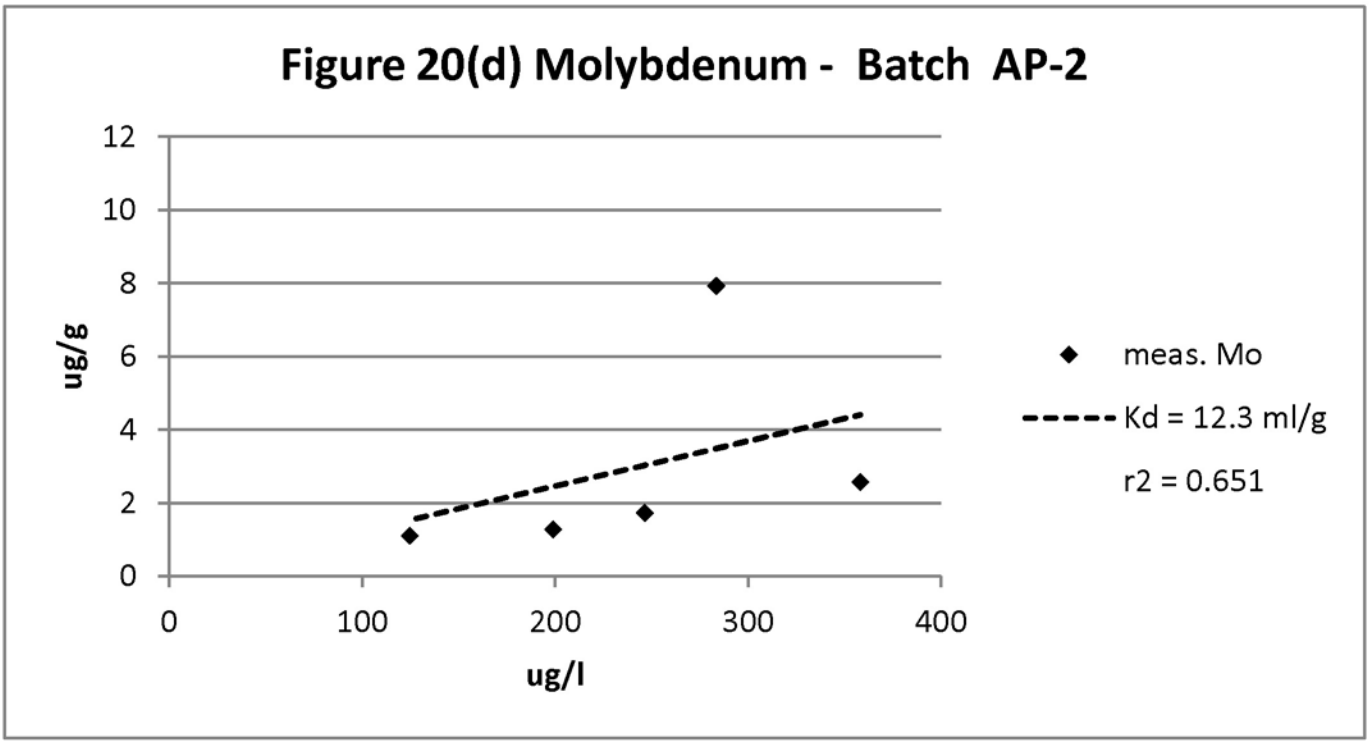


Figure 20(d) Molybdenum - Batch AP-2
12
10
8
6
4
2
0
ug/g
0
100
200
300
400
ug/l
meas. Mo
Kd = 12.3 ml/g
r2 = 0.651

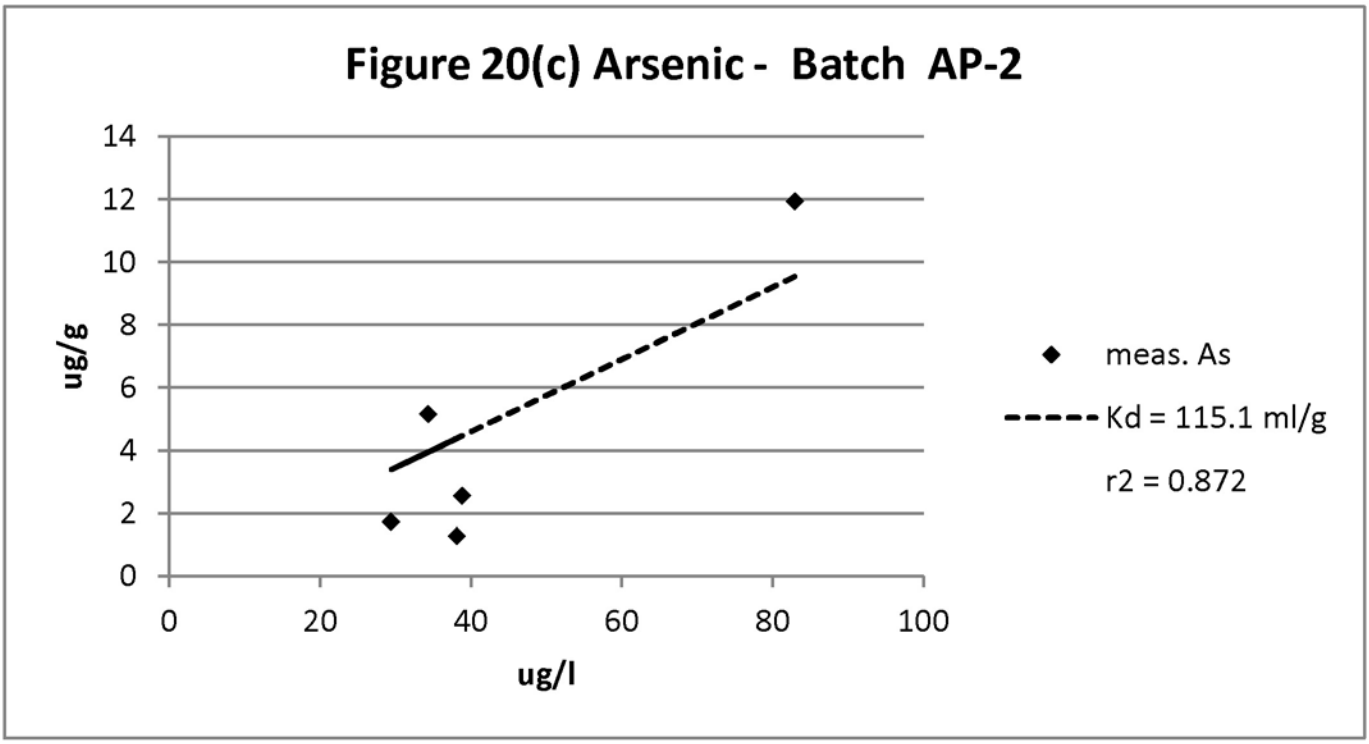


Figure 20(c) Arsenic - Batch AP-2
14
12
10
8
6
4
2
0
ug/g
0
20
40
60
80
100
ug/l
meas. As
Kd = 115.1 ml/g
r2 = 0.872

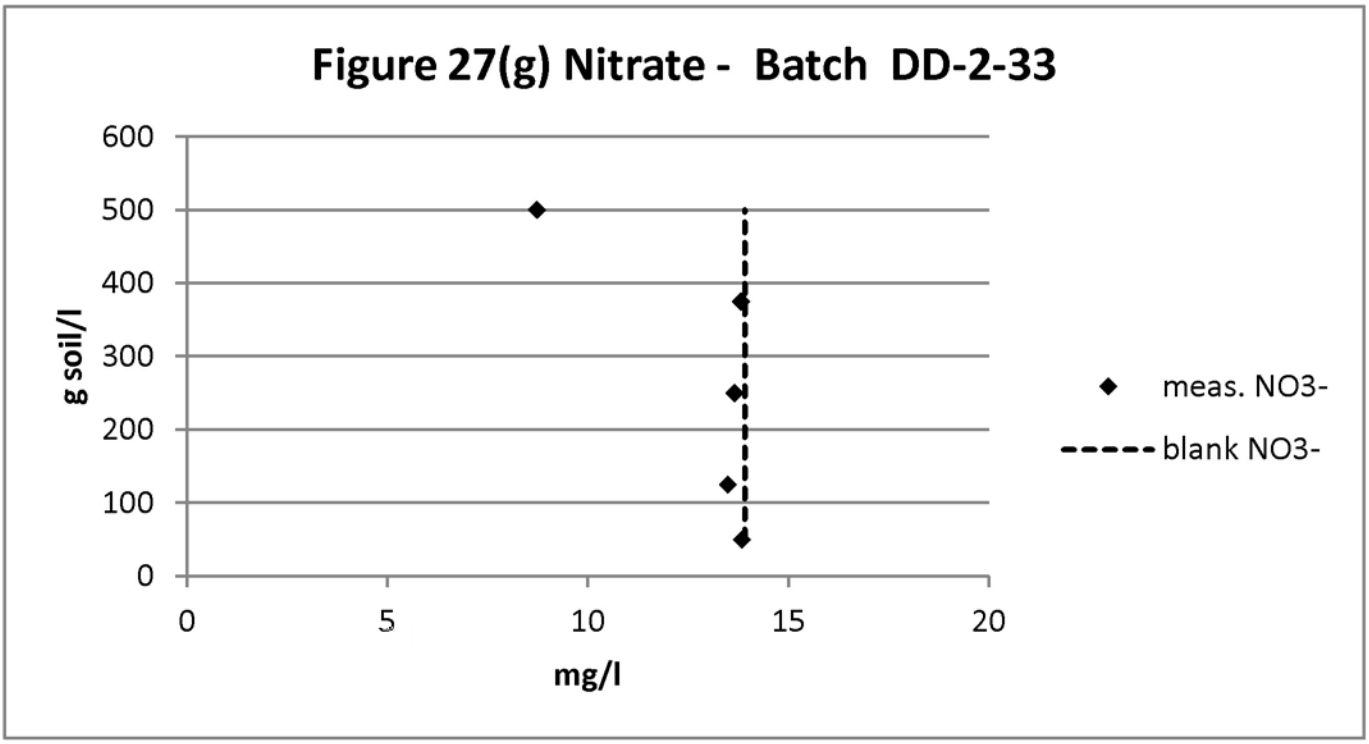


Figure 27(g) Nitrate - Batch DD-2-33
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

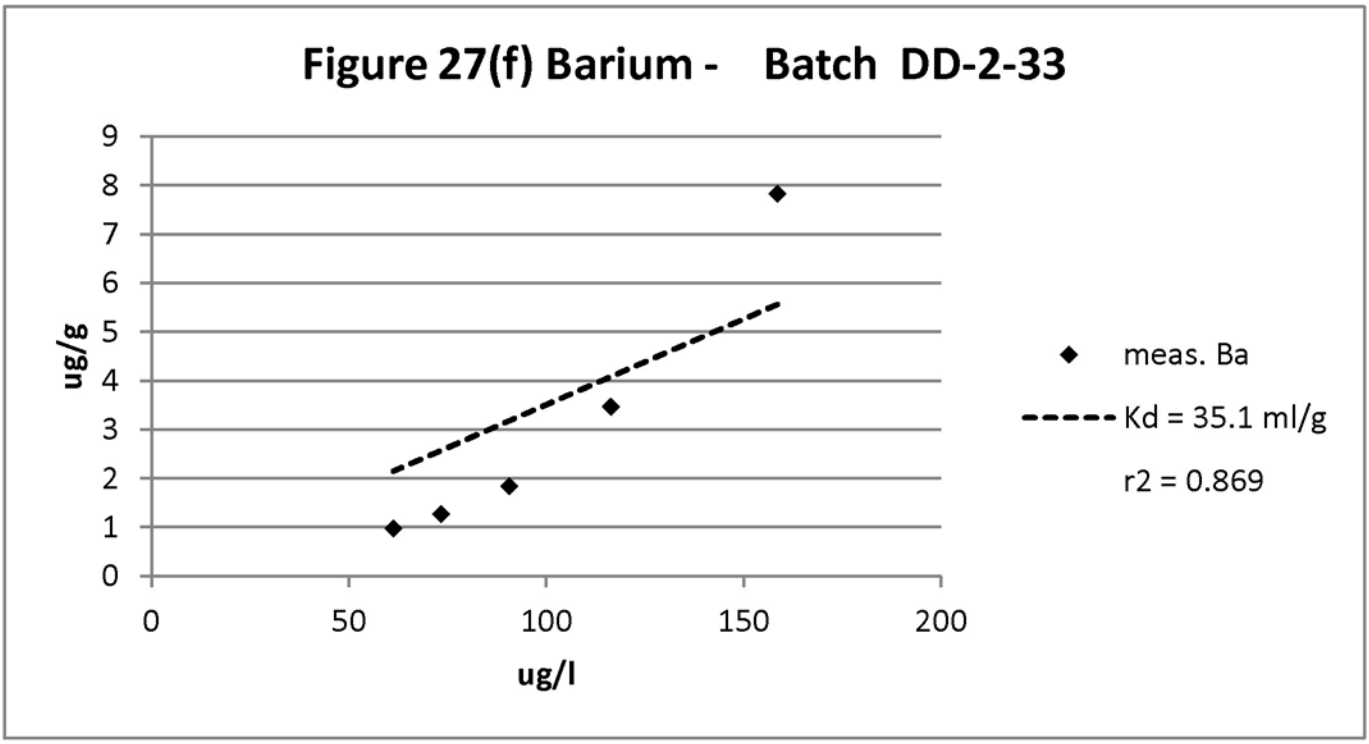


Figure 27(f) Barium - Batch DD-2-33
9
8
7
6
5
4
3
2
1
0
ug/g
0
50
100
150
200
ug/l
meas. Ba
Kd = 35.1 ml/g
r2 = 0.869

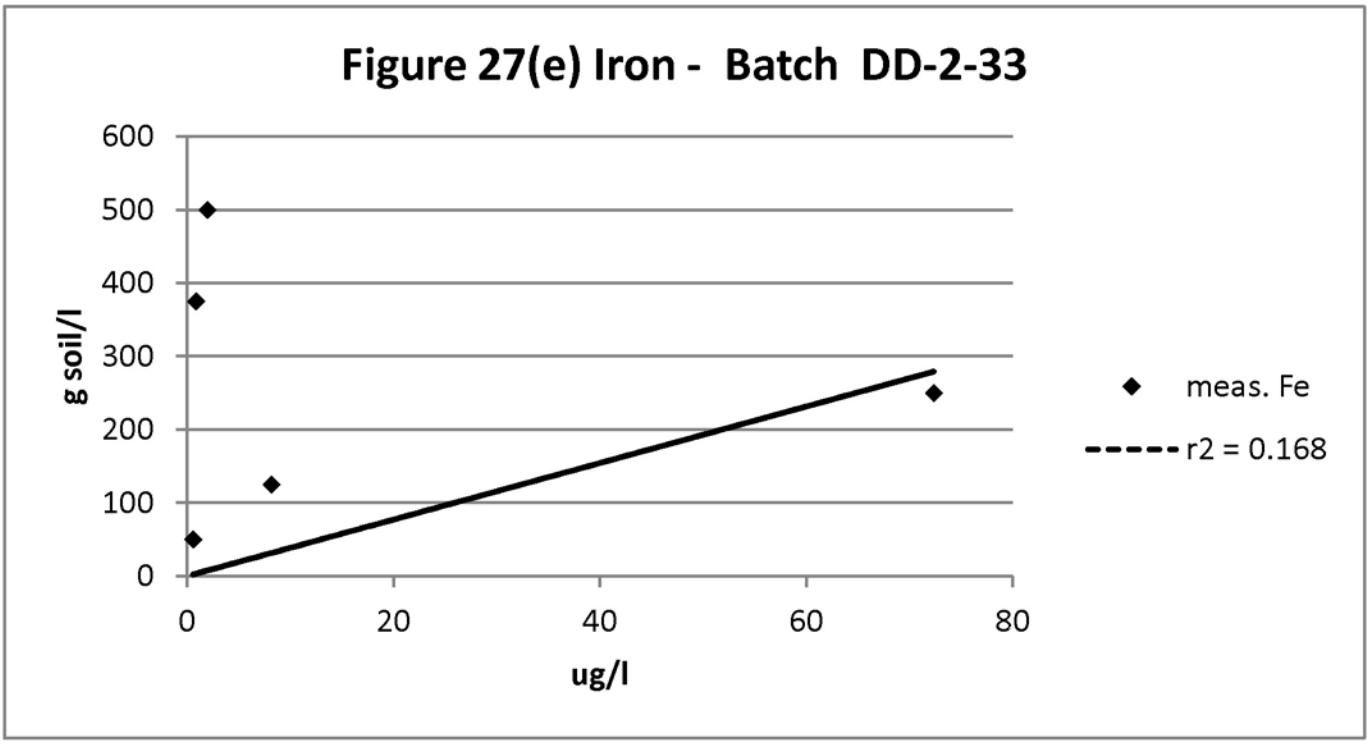


Figure 27(e) Iron - Batch DD-2-33
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
ug/l
meas. Fe
r2 = 0.168

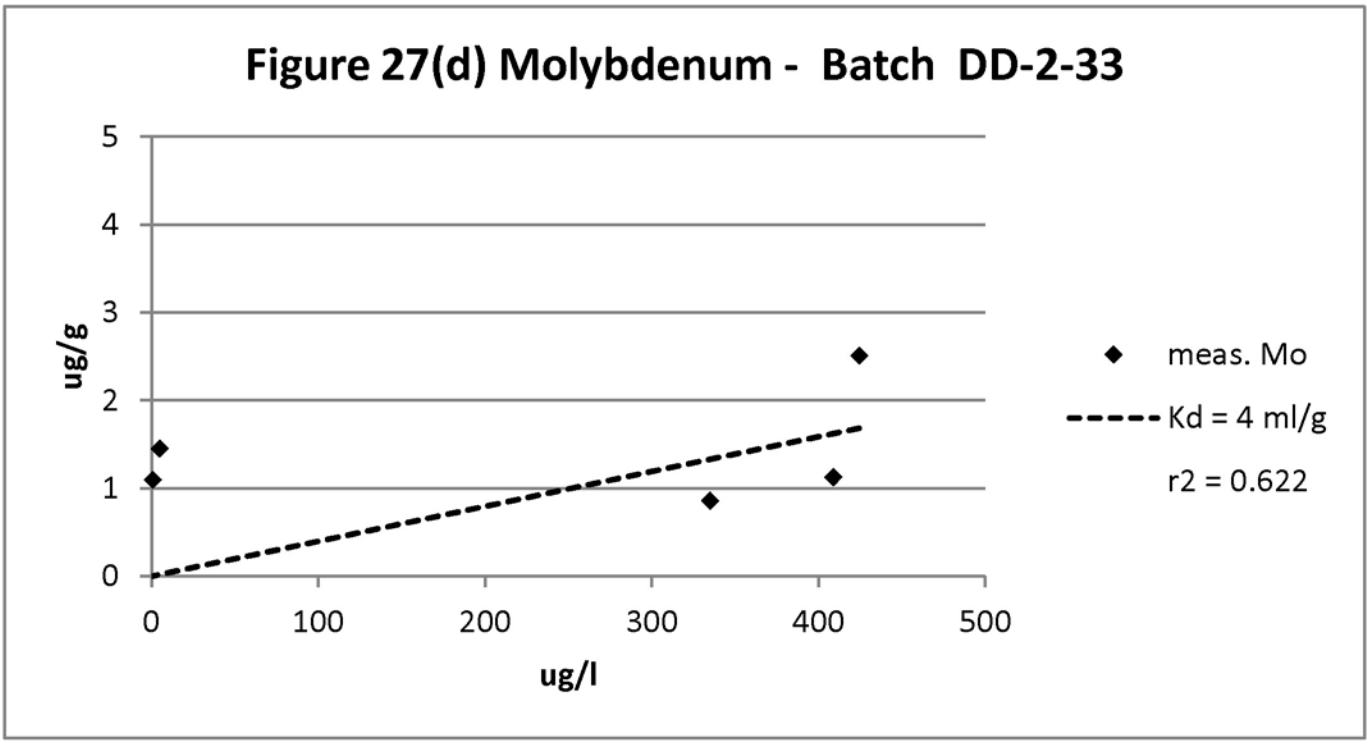


Figure 27(d) Molybdenum - Batch DD-2-33
5
4
3
2
1
0
ug/g
0
100
200
300
400
500
ug/l
meas. Mo
Kd = 4 ml/g
r2 = 0.622

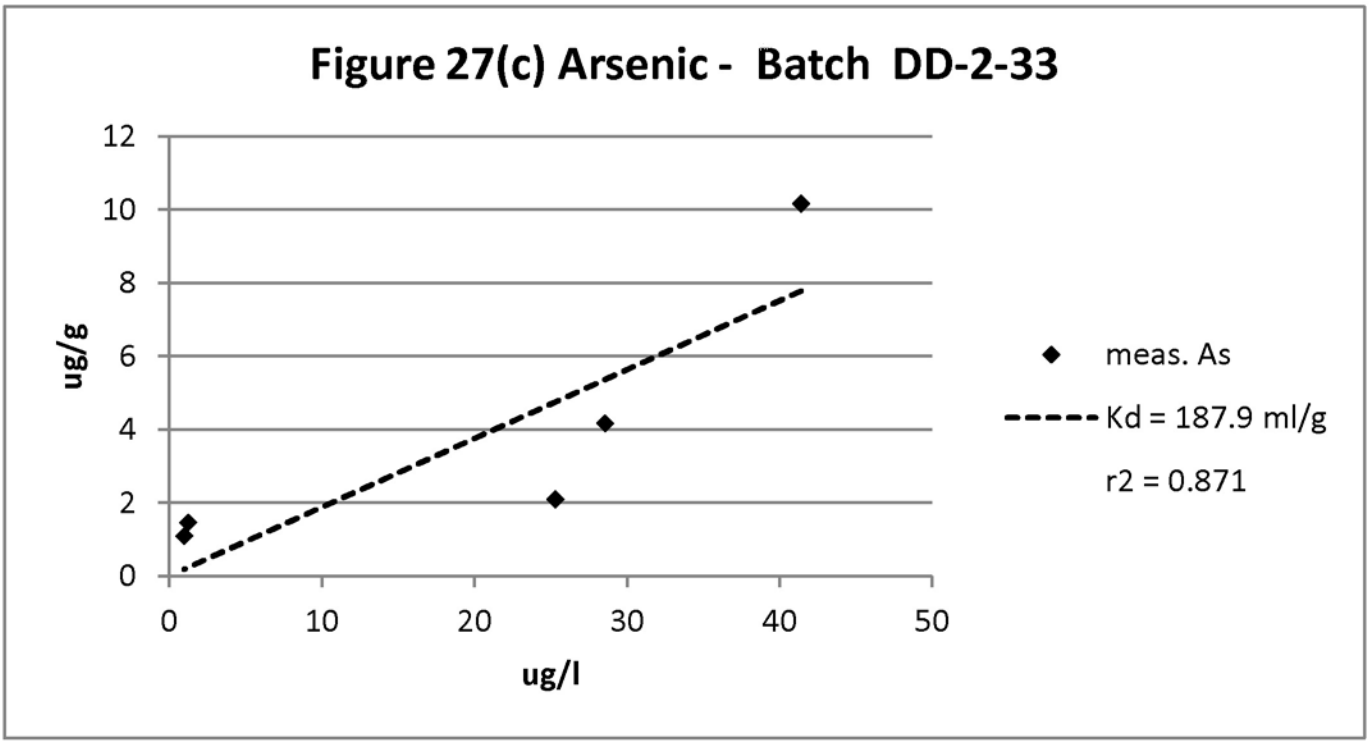


Figure 27(c) Arsenic - Batch DD-2-33
12
10
8
6
4
2
0
ug/g
0
10
20
30
40
50
ug/l
meas. As
Kd = 187.9 ml/g
r2 = 0.871

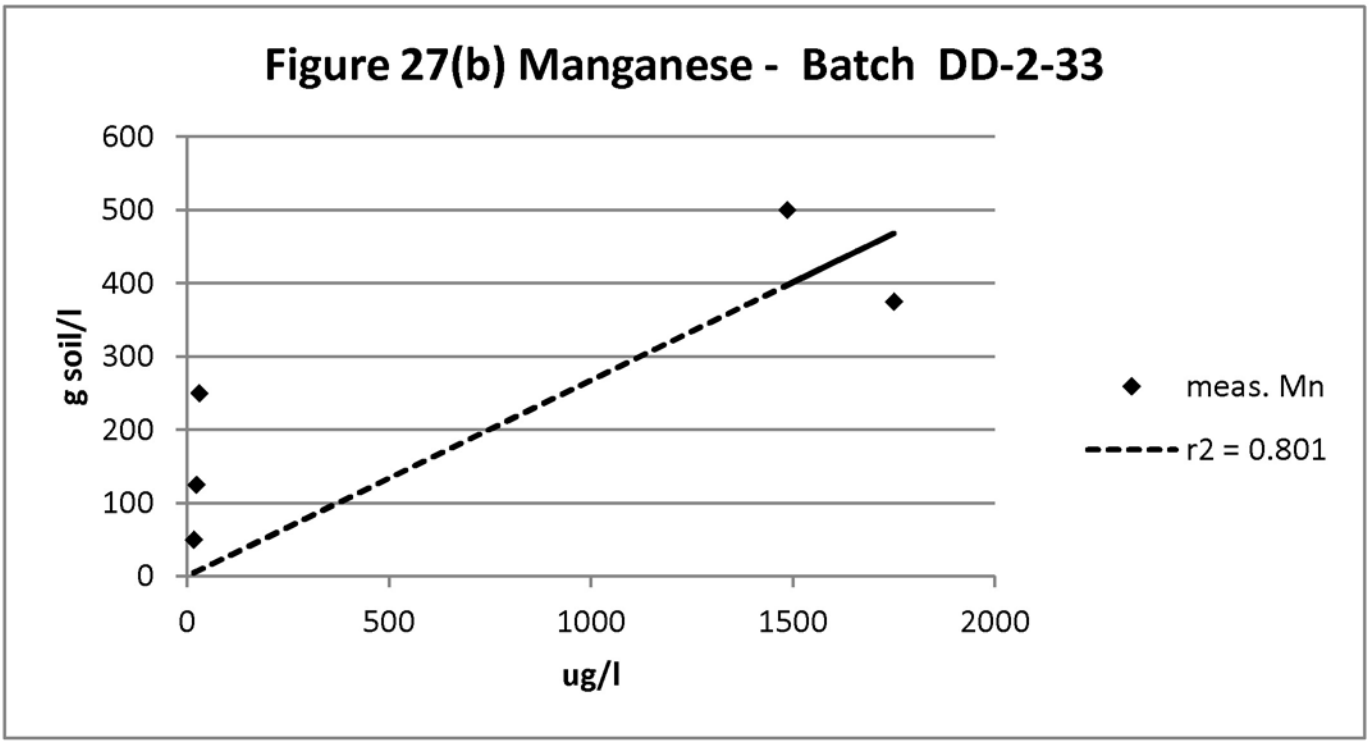


Figure 27(b) Manganese - Batch DD-2-33
600
500
400
300
200
100
0
g soil/l
0
500
1000
1500
2000
ug/l
meas. Mn
r2 = 0.801

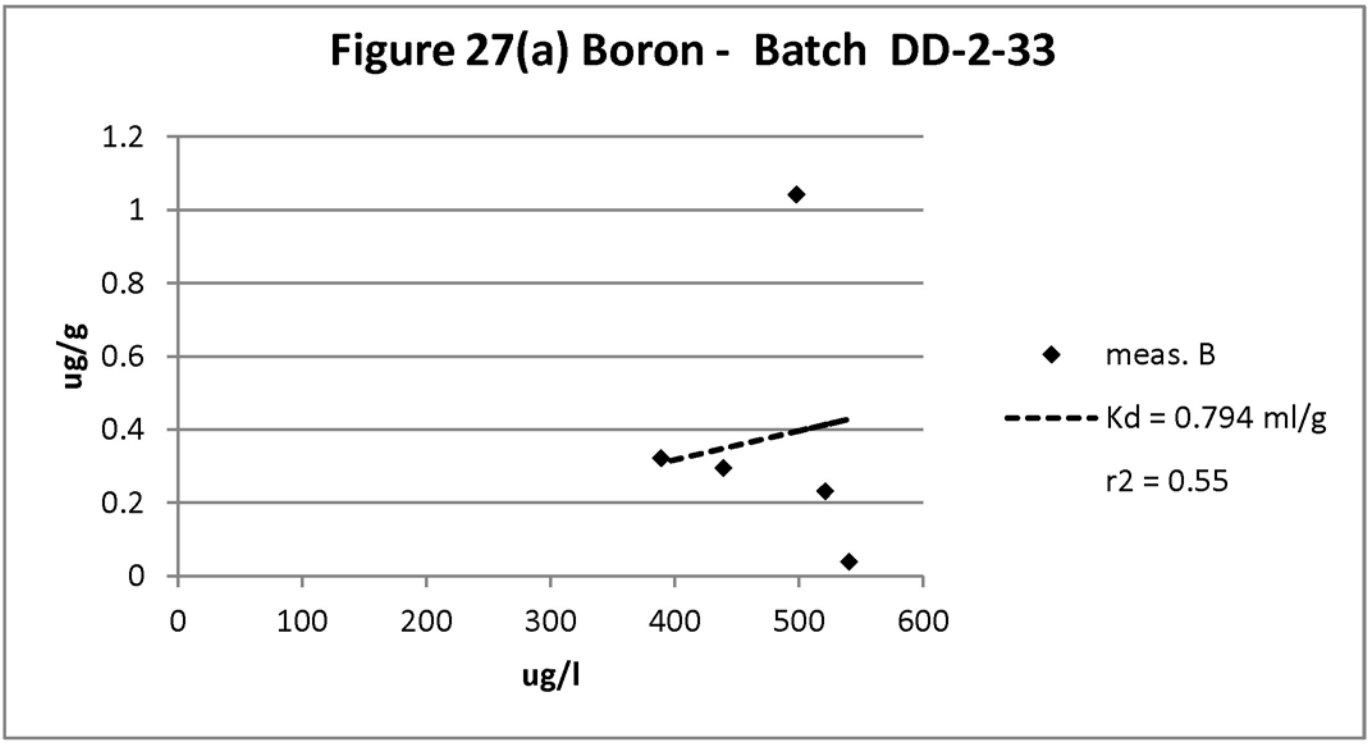


Figure 27(a) Boron - Batch DD-2-33
1.2
1
0.8
0.6
0.4
0.2
0
ug/g
0
100
200
300
400
500
600
ug/l
meas. B
Kd = 0.794 ml/g
r2 = 0.55

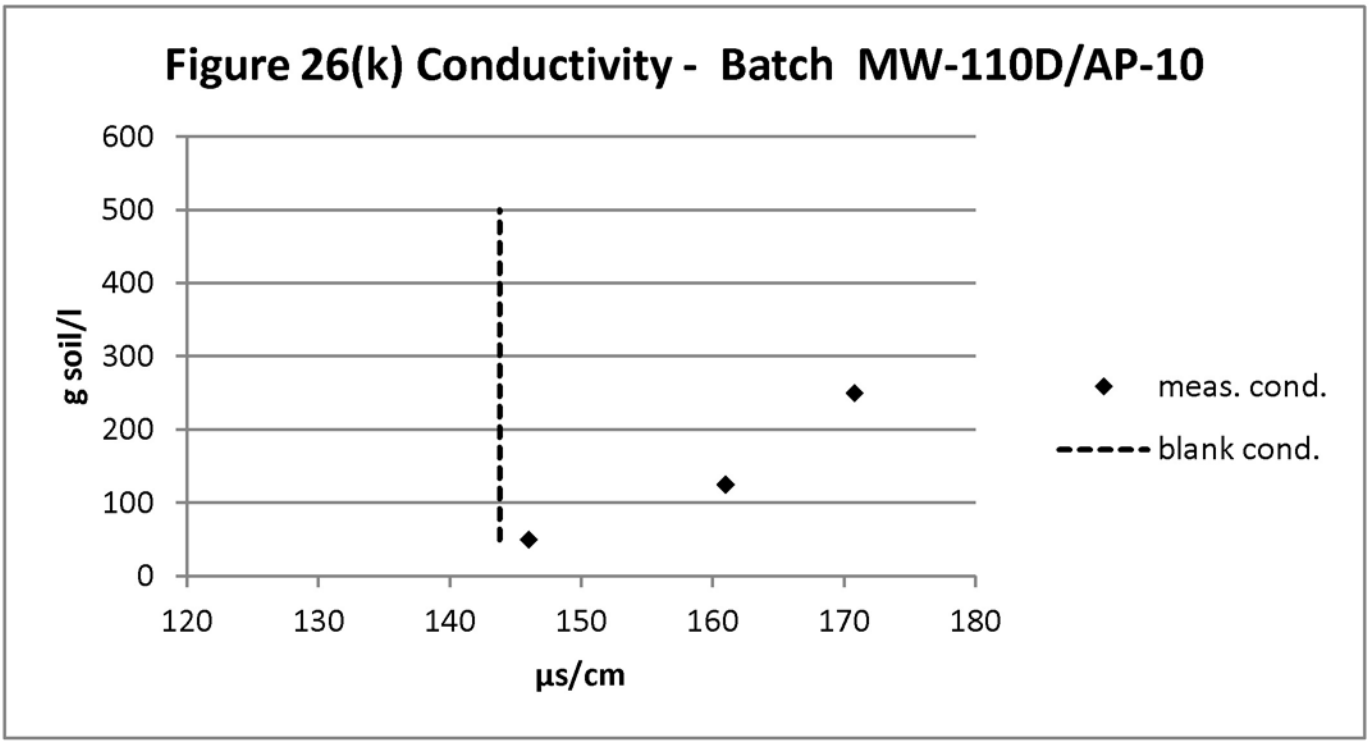


Figure 26(k) Conductivity - Batch MW-110D/AP-10
600
500
400
300
200
100
0
g soil/l
120
130
140
150
160
170
180
µs/cm
meas. cond.
blank cond.

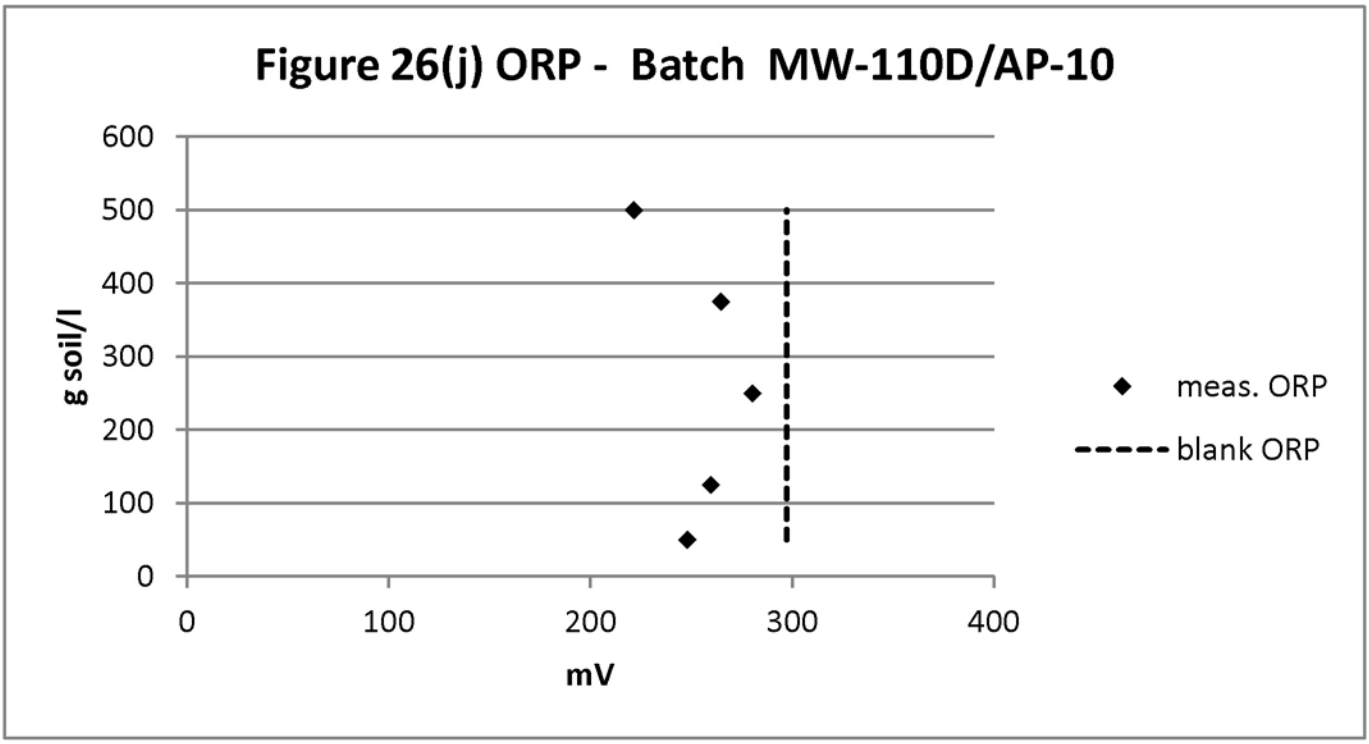


Figure 26(j) ORP - Batch MW-110D/AP-10
600
500
400
300
200
100
0
g soil/l
0
100
200
300
400
mV
meas. ORP
blank ORP

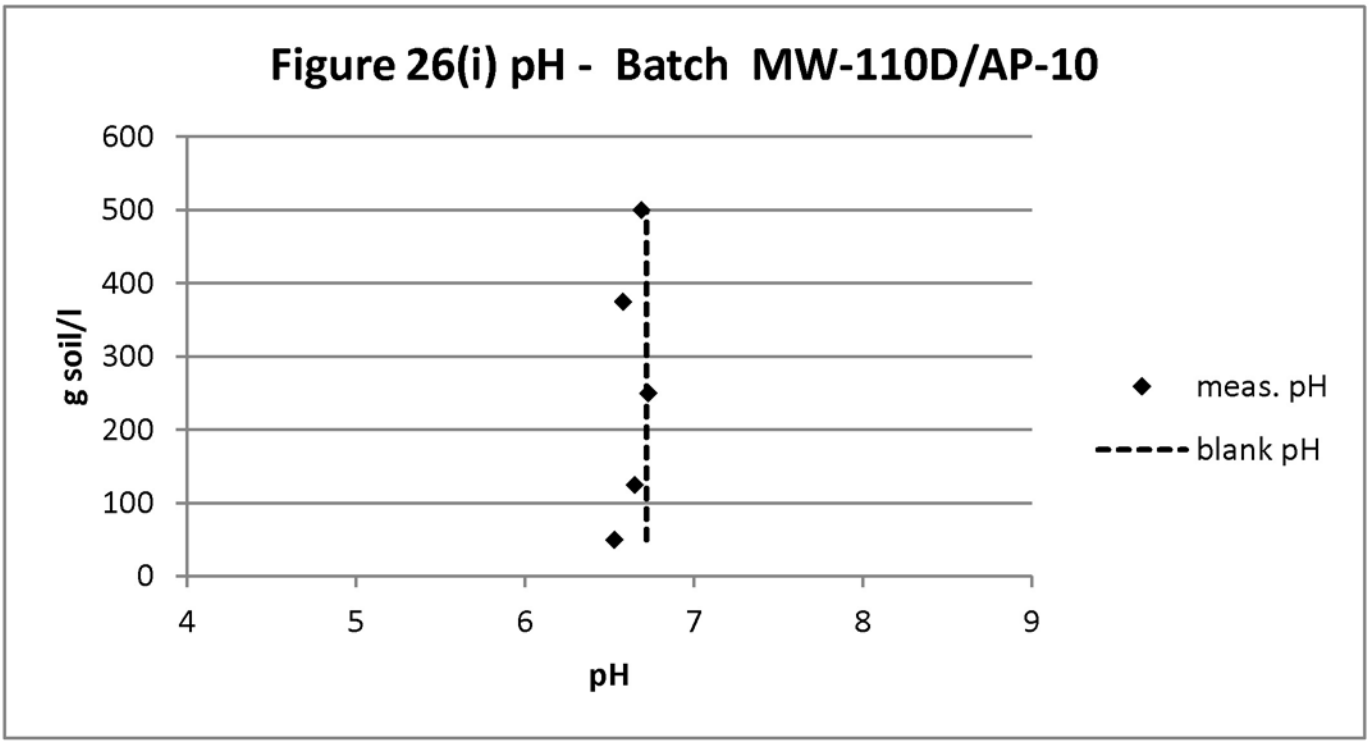


Figure 26(i) pH - Batch MW-110D/AP-10
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

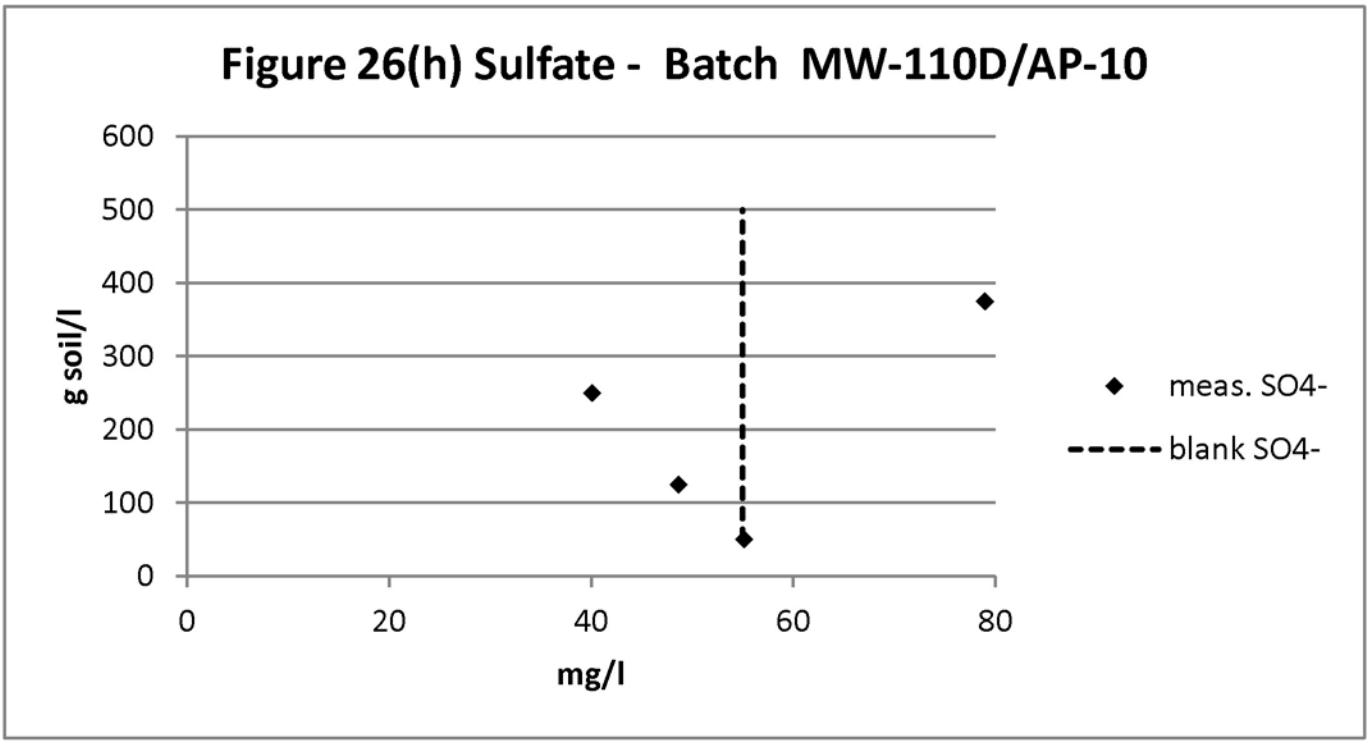


Figure 26(h) Sulfate - Batch MW-110D/AP-10
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

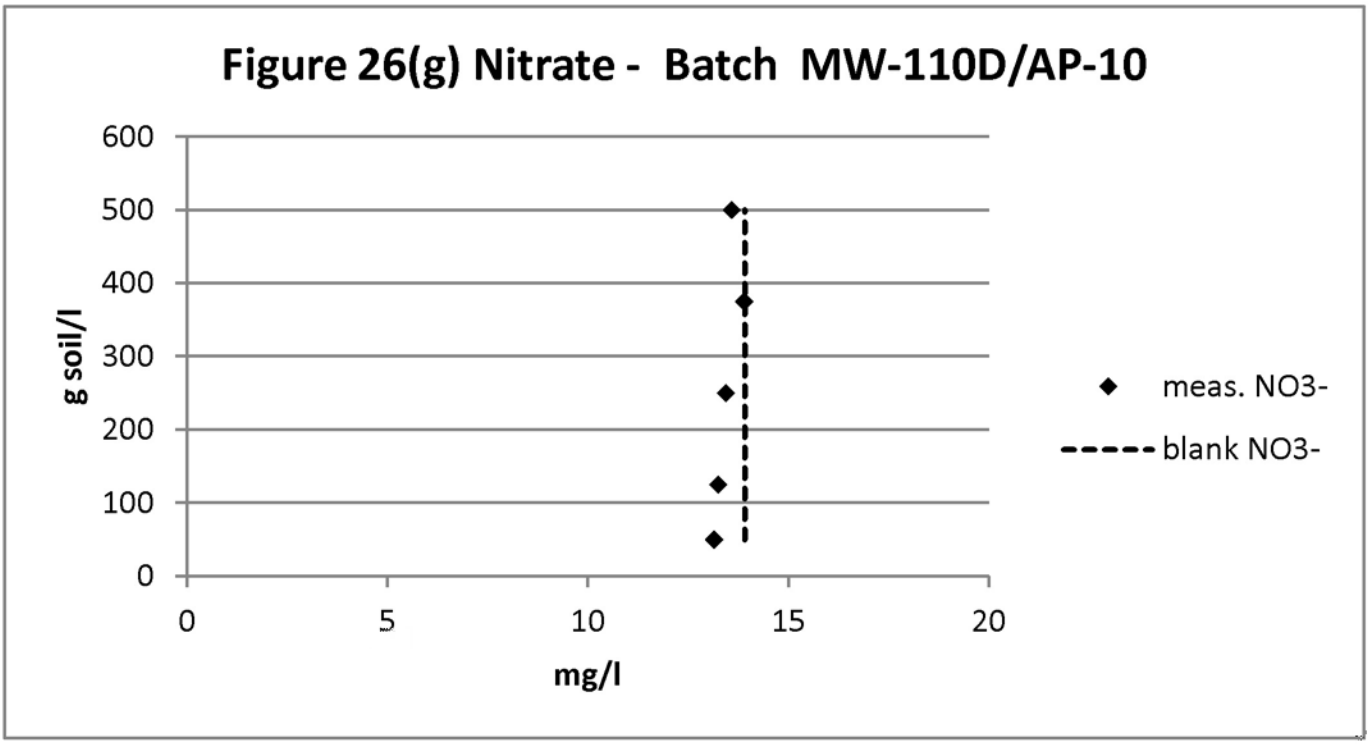


Figure 26(g) Nitrate - Batch MW-110D/AP-10
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

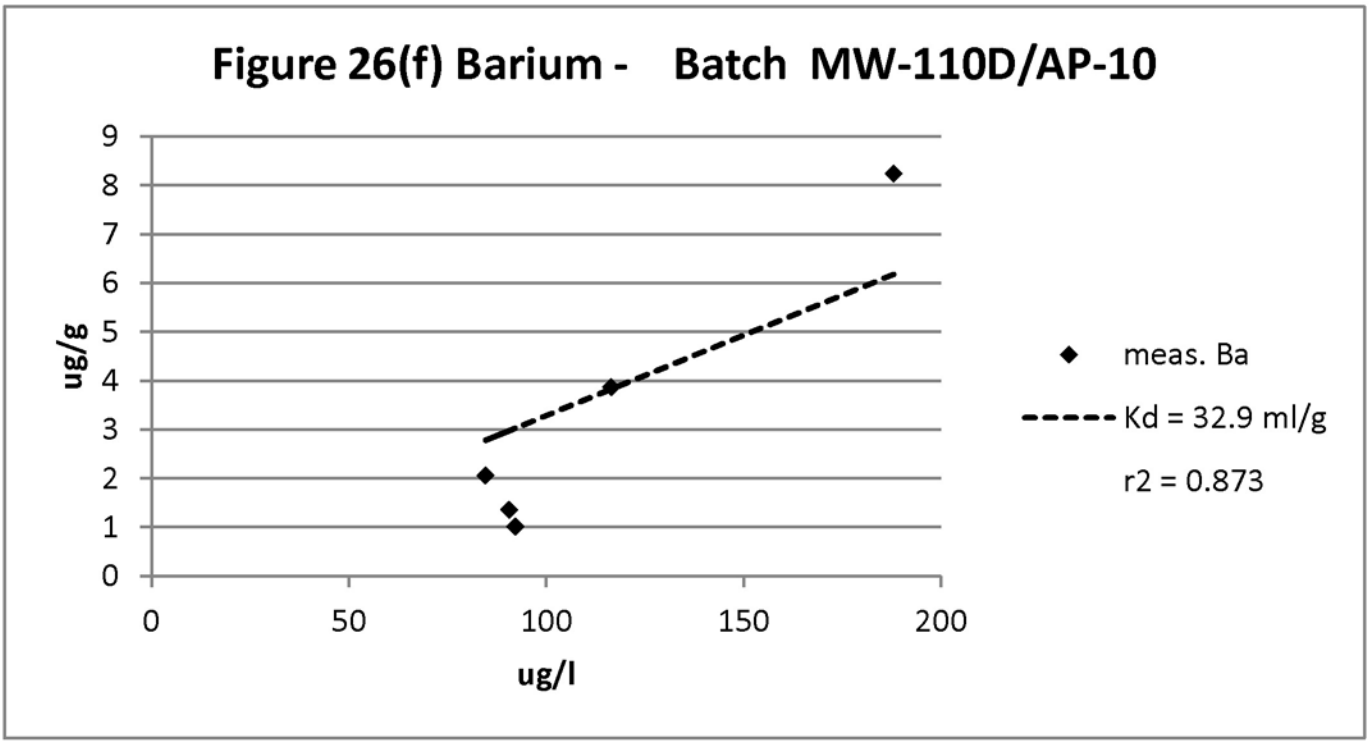


Figure 26(f) Barium - Batch MW-110D/AP-10
9
8
7
6
5
4
3
2
1
0
ug/g
0
50
100
150
200
ug/l
meas. Ba
Kd = 32.9 ml/g
r2 = 0.873

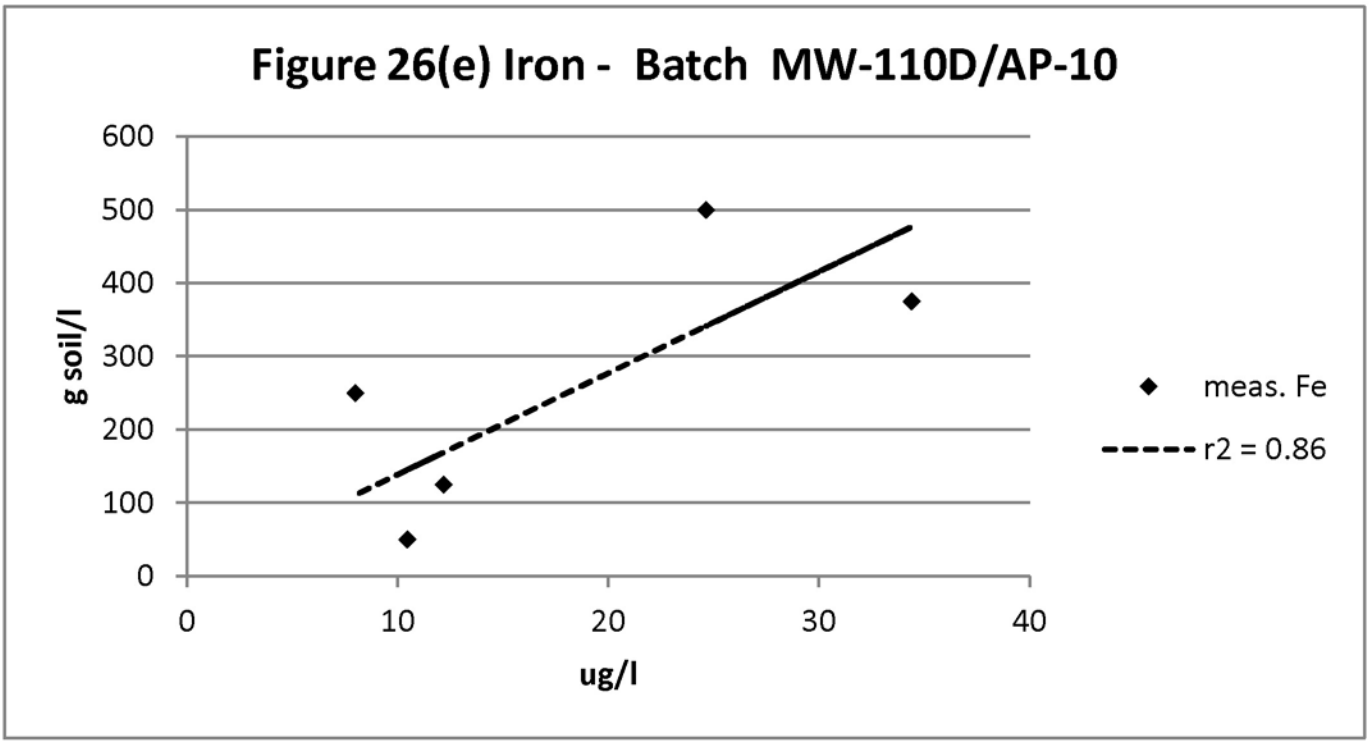


Figure 26(e) Iron - Batch MW-110D/AP-10
600
500
400
300
200
100
0
g soil/l
0
10
20
30
40
ug/l
meas. Fe
r2 = 0.86

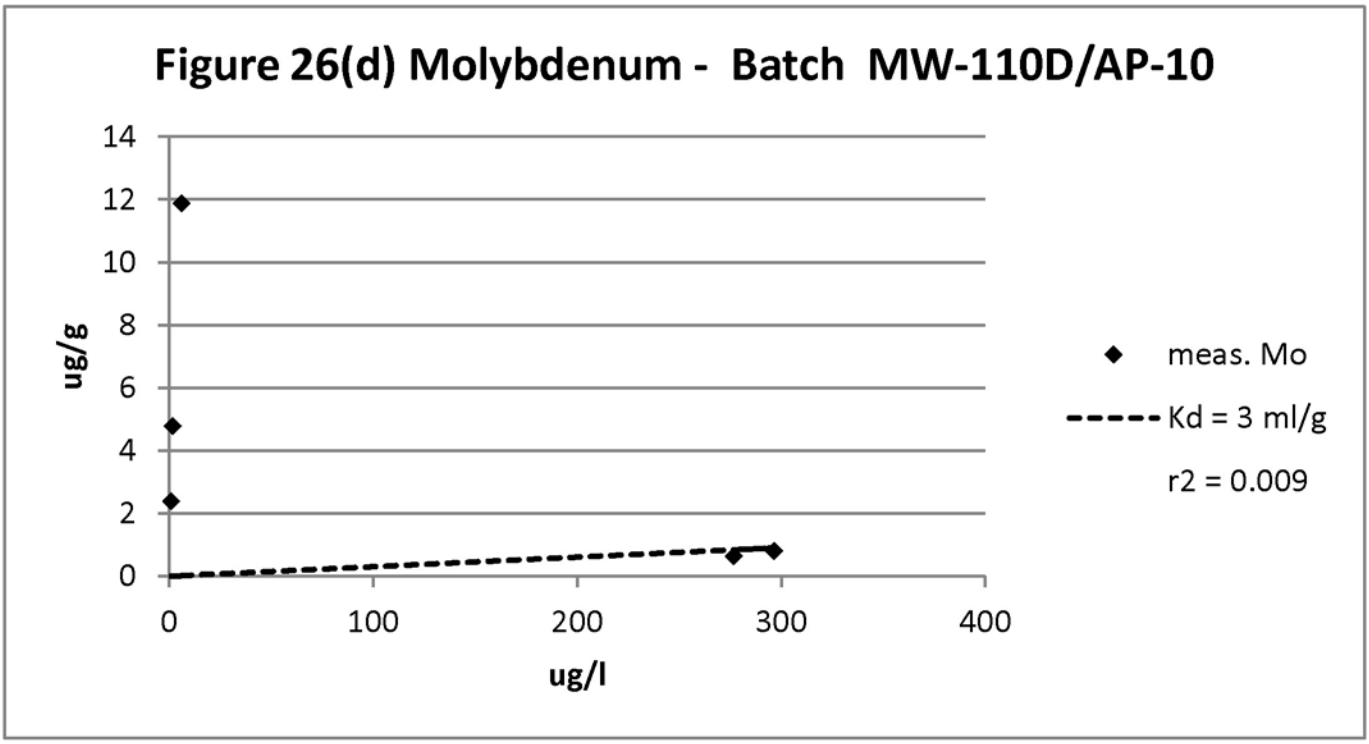


Figure 26(d) Molybdenum - Batch MW-110D/AP-10
14
12
10
8
6
4
2
0
ug/g
0
100
200
300
400
ug/l
meas. Mo
Kd = 3 ml/g
r2 = 0.009

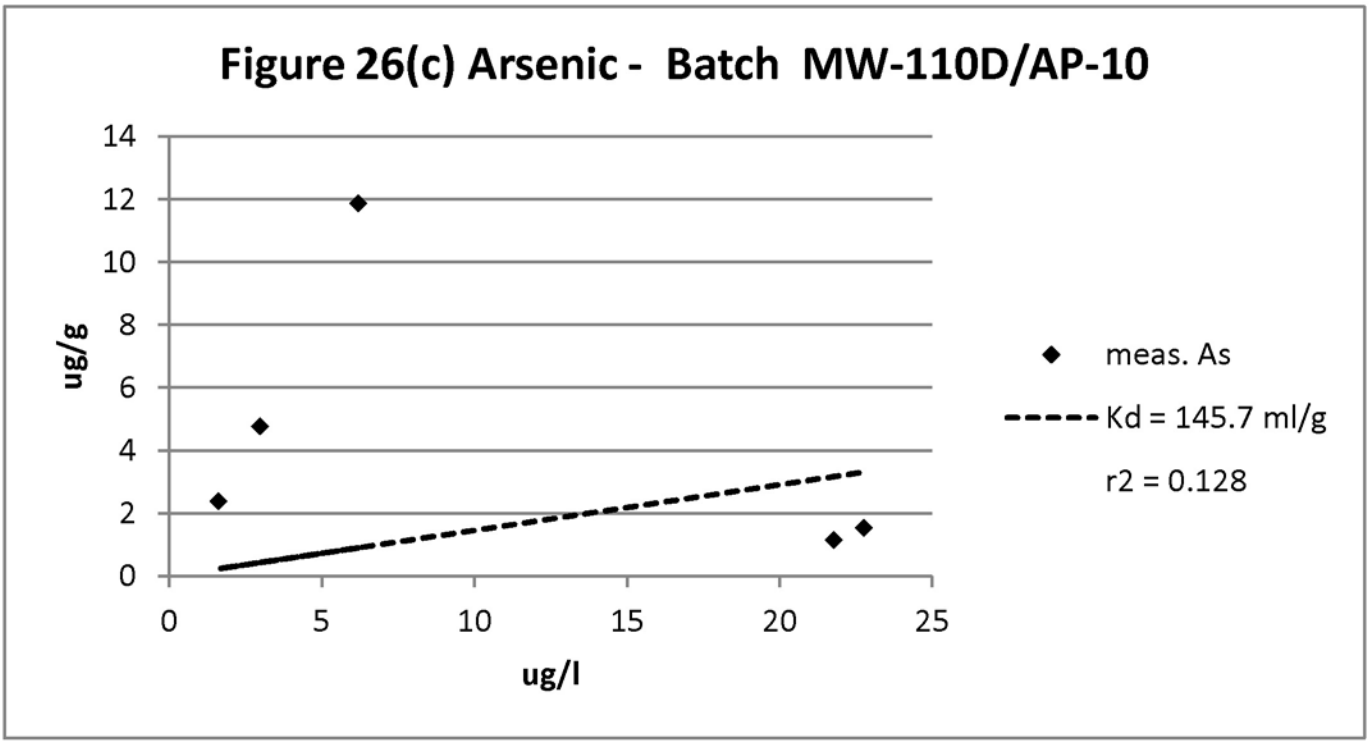


Figure 26(c) Arsenic - Batch MW-110D/AP-10
14
12
10
8
6
4
2
0
ug/g
0
5
10
15
20
25
ug/l
meas. As
Kd = 145.7 ml/g
r2 = 0.128

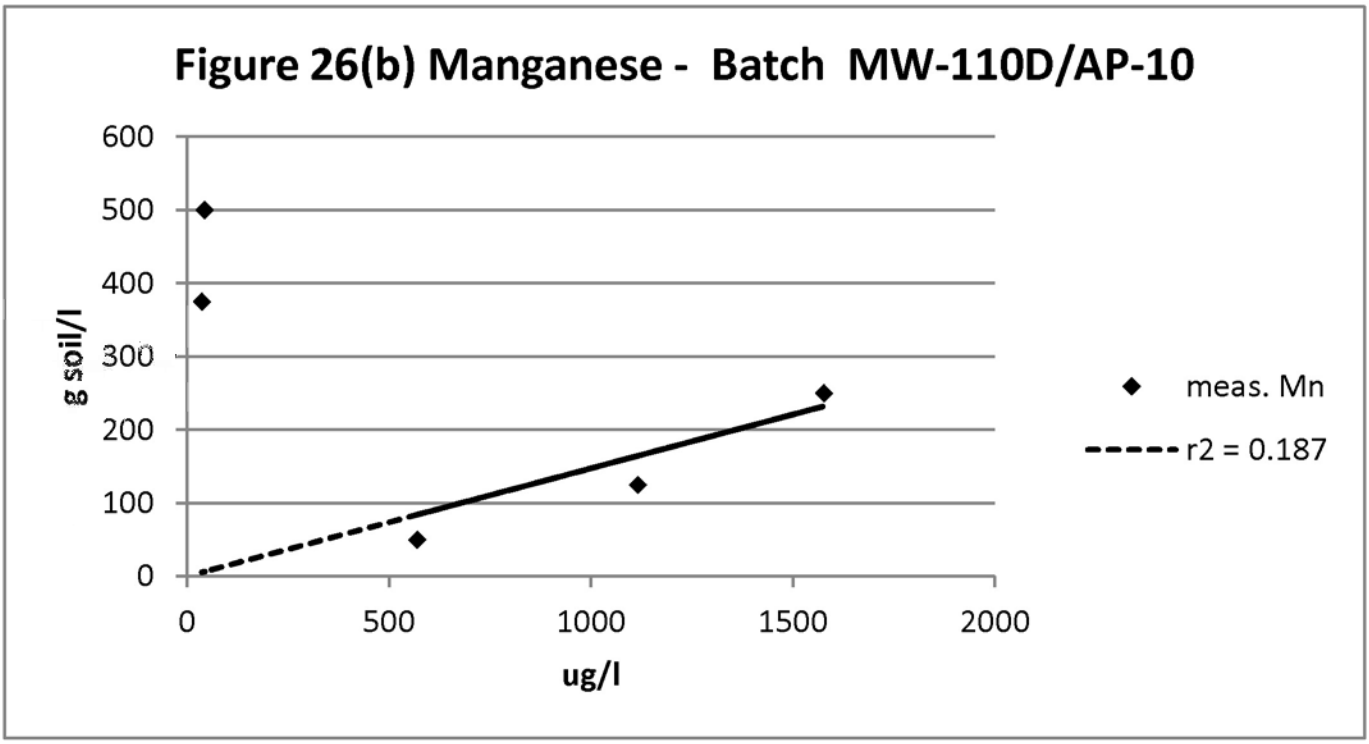


Figure 26(b) Manganese - Batch MW-110D/AP-10
600
500
400
300
200
100
0
g soil/l
0
500
1000
1500
2000
ug/l
meas. Mn
r2 = 0.187

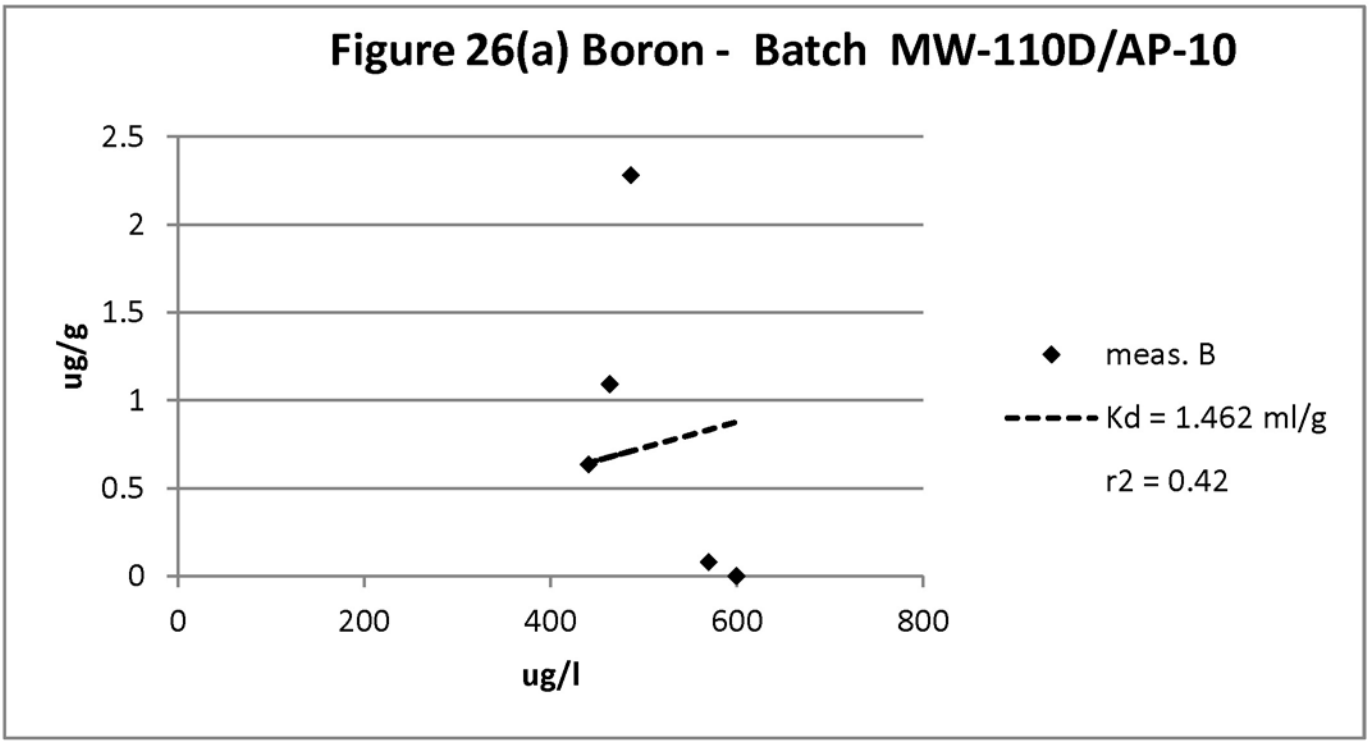


Figure 26(a) Boron - Batch MW-110D/AP-10
2.5
2
1.5
1
0.5
0
ug/g
0
200
400
600
800
ug/l
meas. B
Kd = 1.462 ml/g
r2 = 0.42

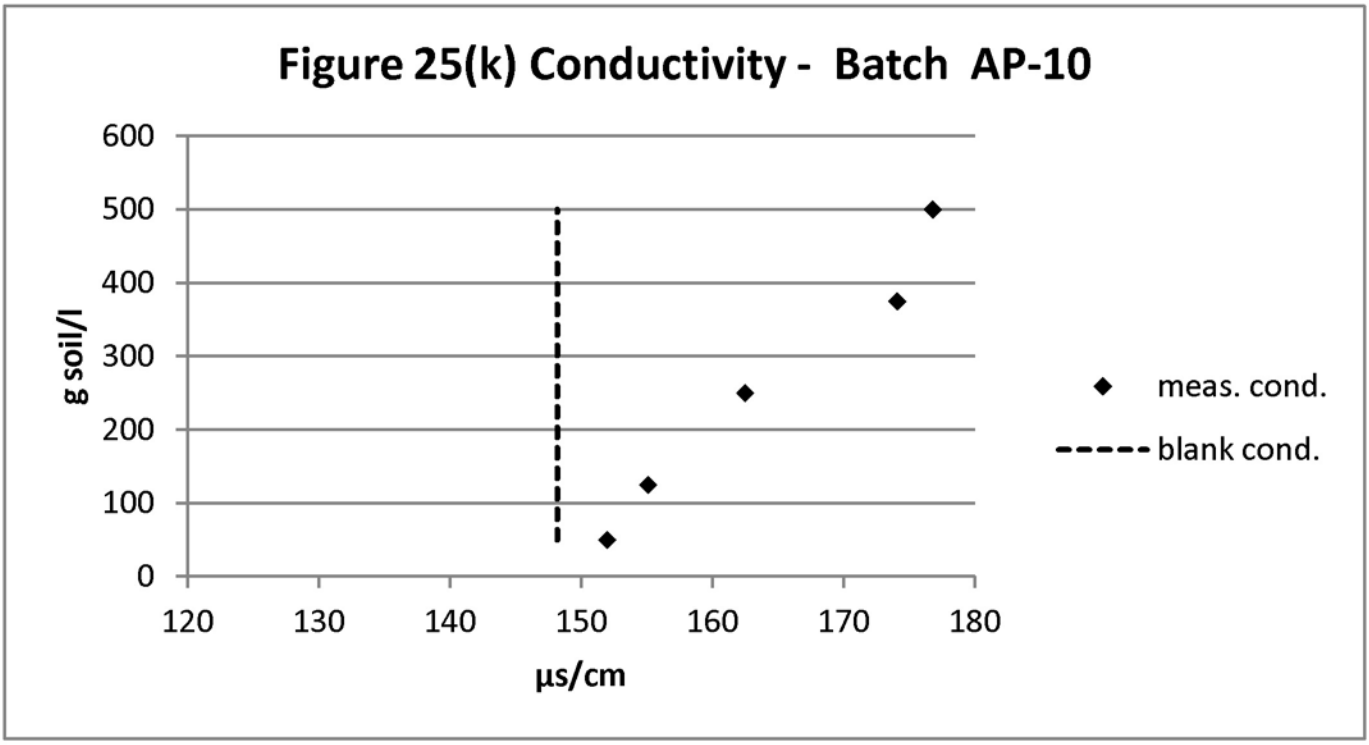


Figure 25(k) Conductivity - Batch AP-10
600
500
400
300
200
100
0
g soil/l
120
130
140
150
160
170
180
µs/cm
meas. cond.
blank cond.

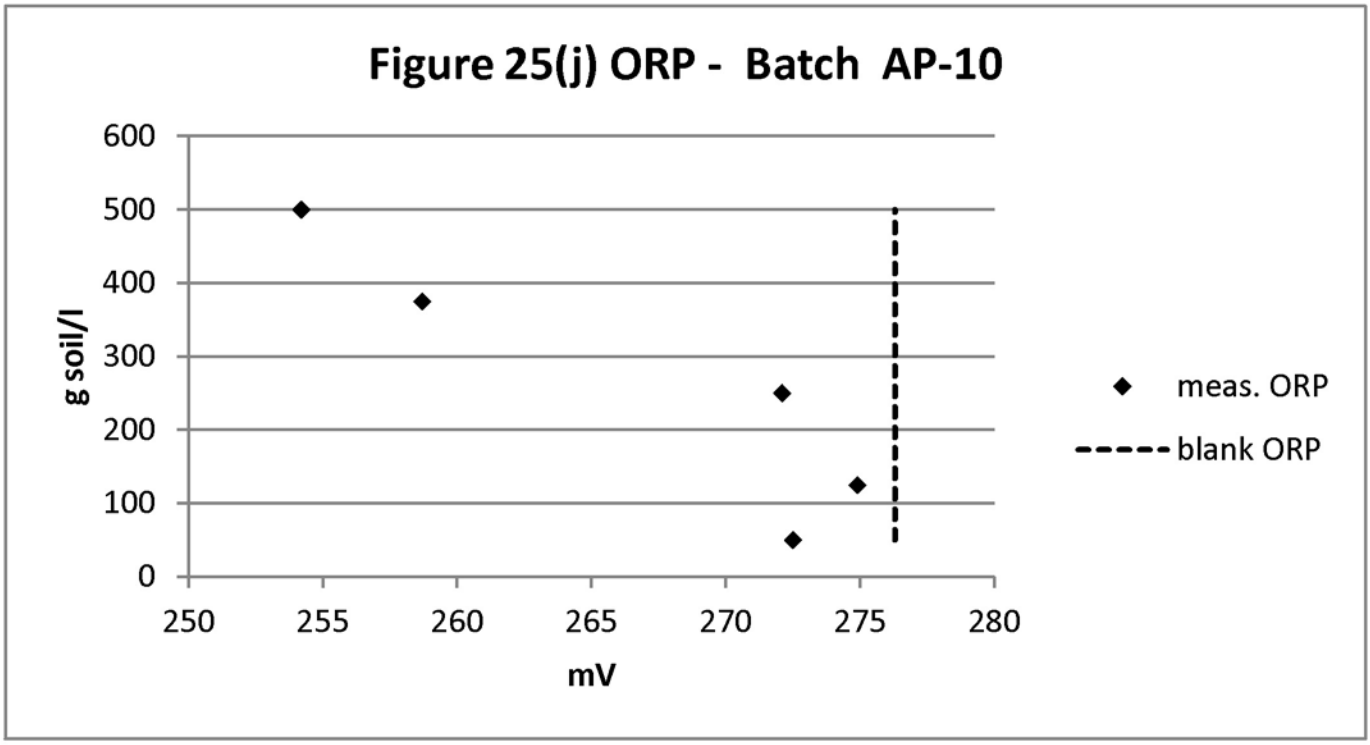


Figure 25(j) ORP - Batch AP-10
600
500
400
300
200
100
0
g soil/l
250
255
260
265
270
275
280
mV
meas. ORP
blank ORP

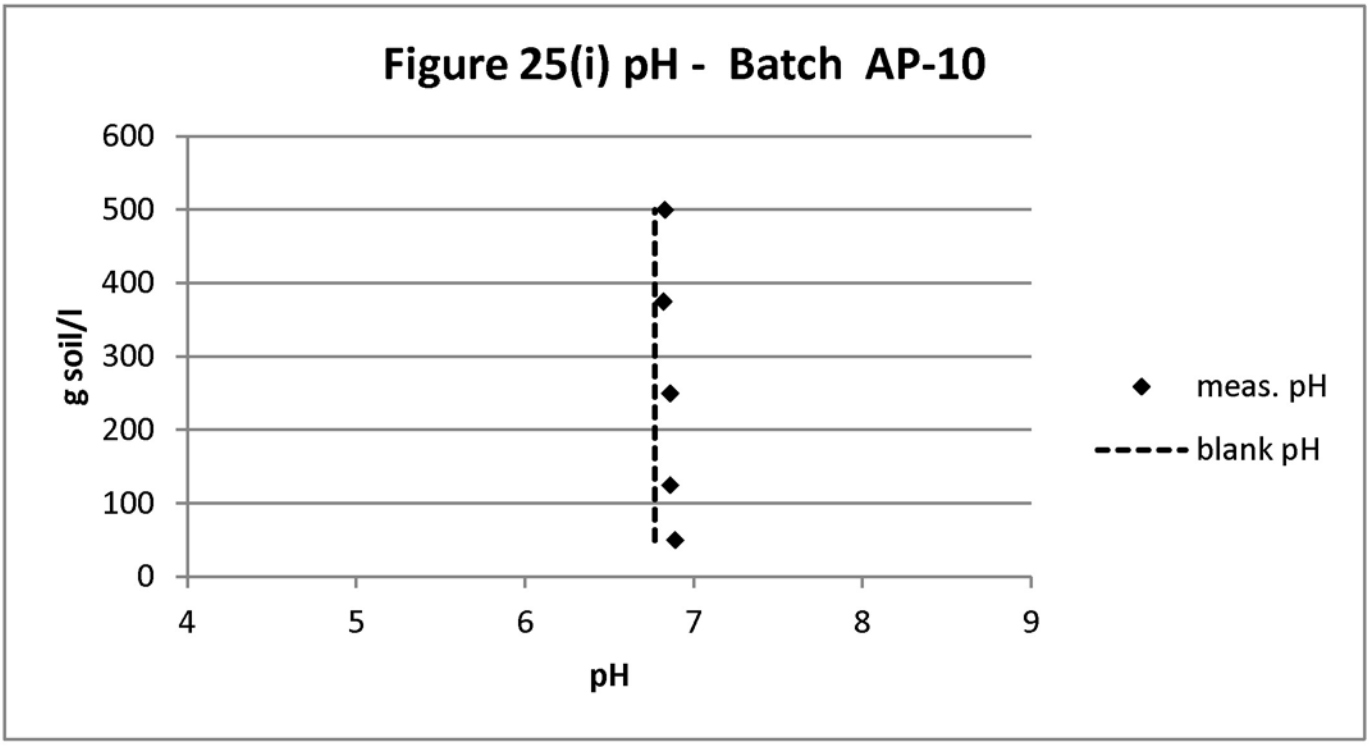


Figure 25(i) pH - Batch AP-10
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

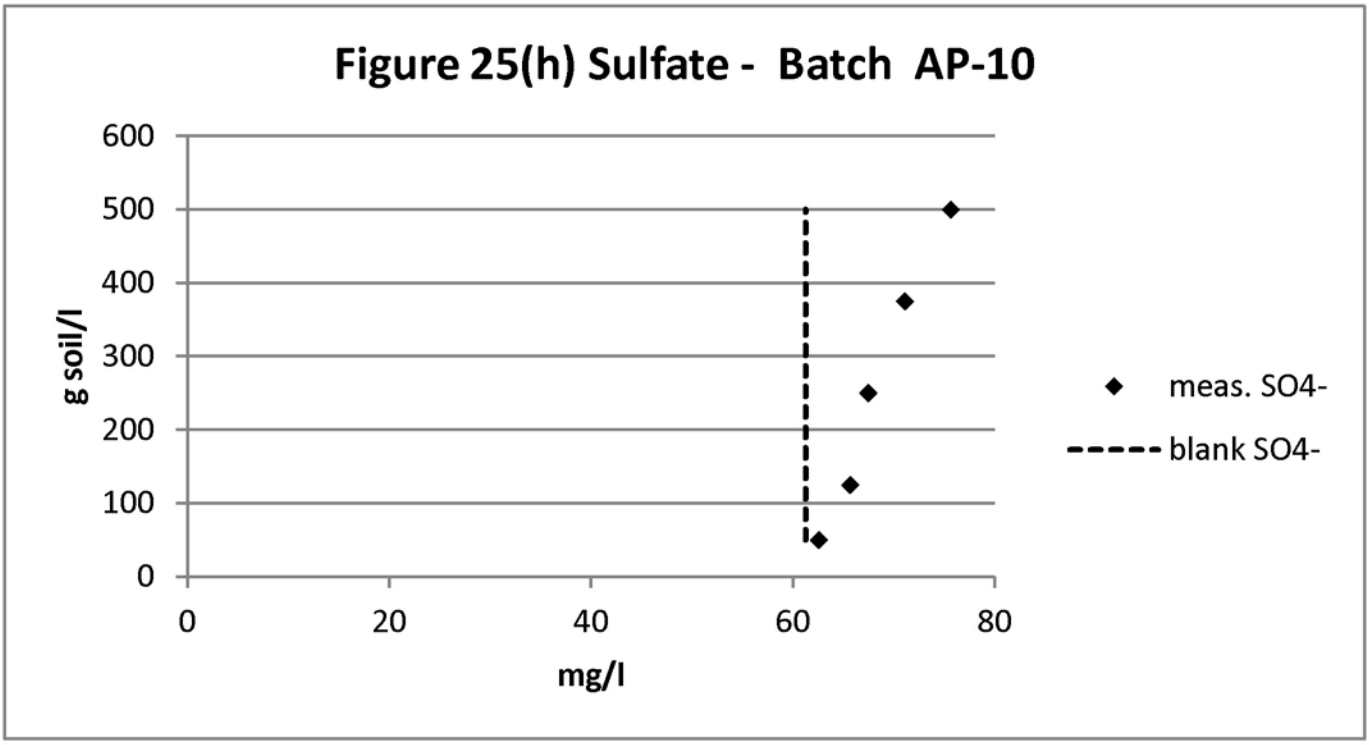


Figure 25(h) Sulfate - Batch AP-10
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

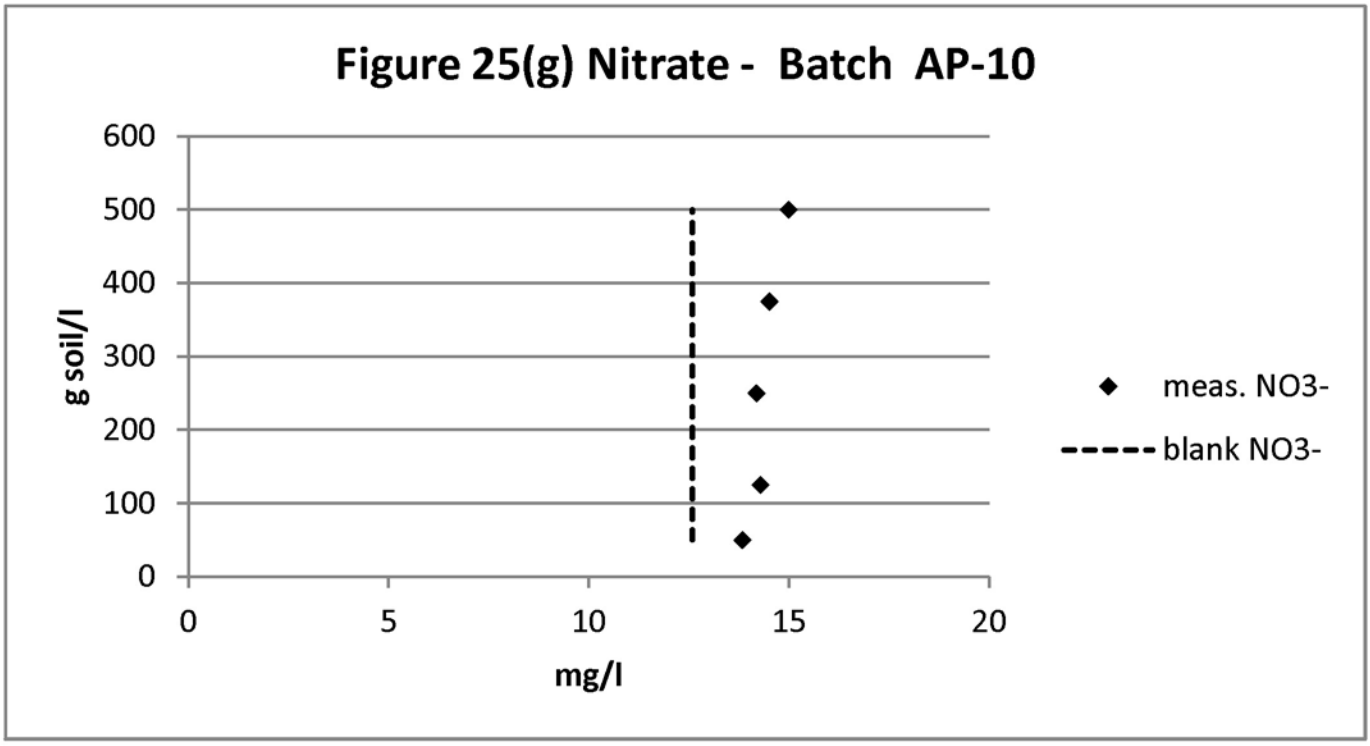


Figure 25(g) Nitrate - Batch AP-10
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

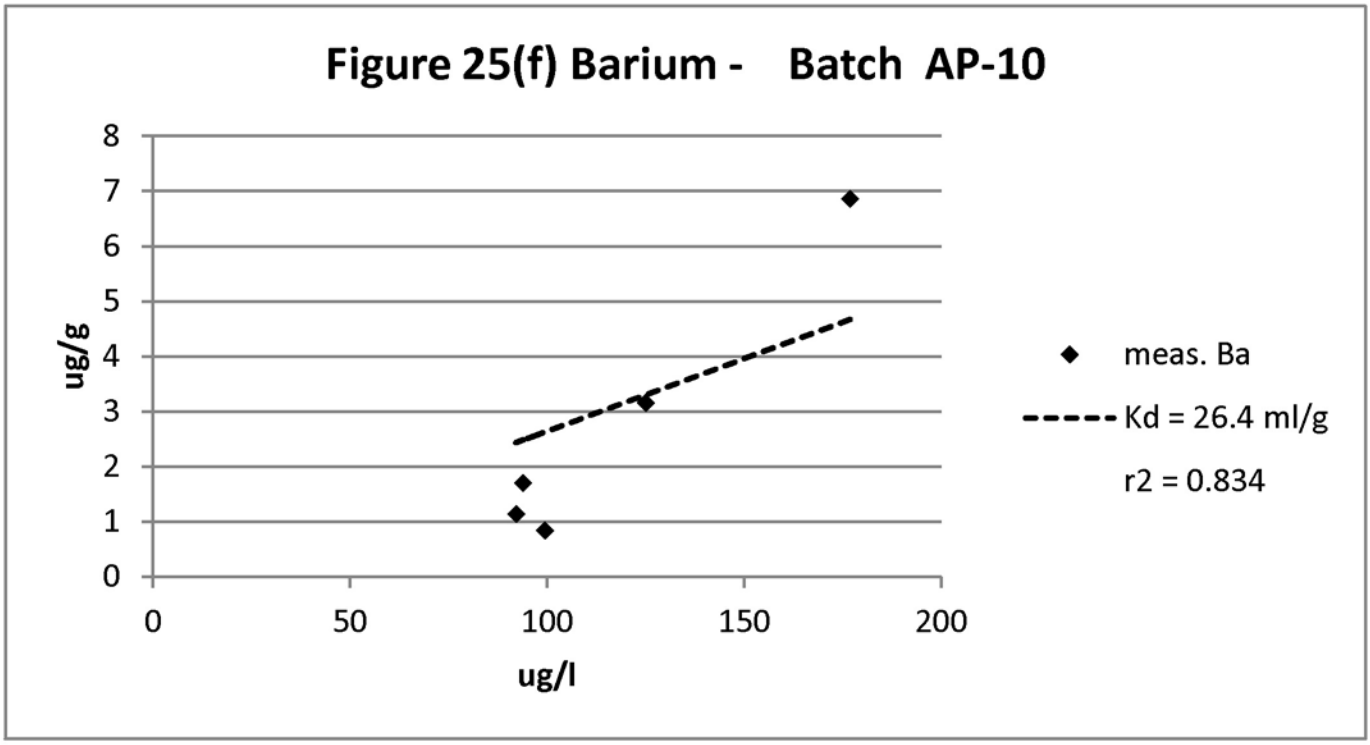


Figure 25(f) Barium - Batch AP-10
8
7
6
5
4
3
2
1
0
ug/g
0
50
100
150
200
ug/l
meas. Ba
Kd = 26.4 ml/g
r2 = 0.834

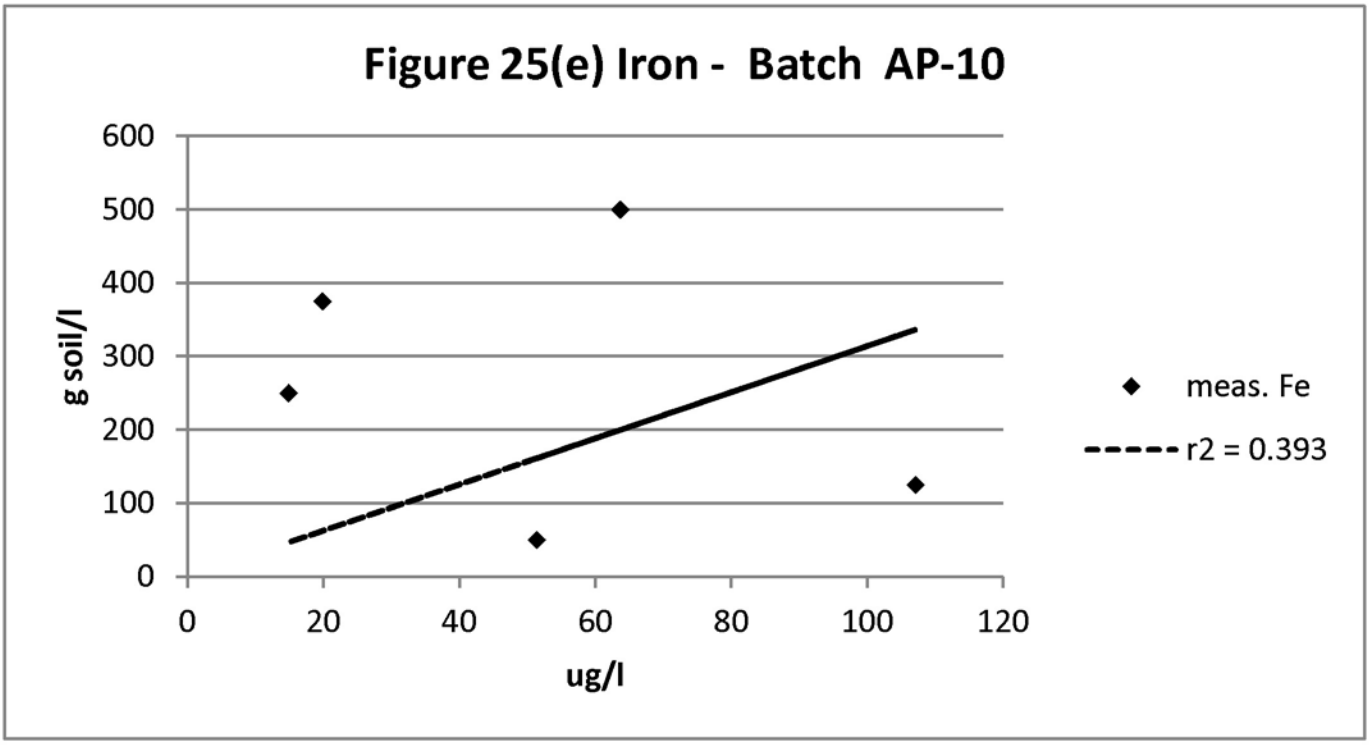


Figure 25(e) Iron - Batch AP-10
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
100
120
ug/l
meas. Fe
r2 = 0.393

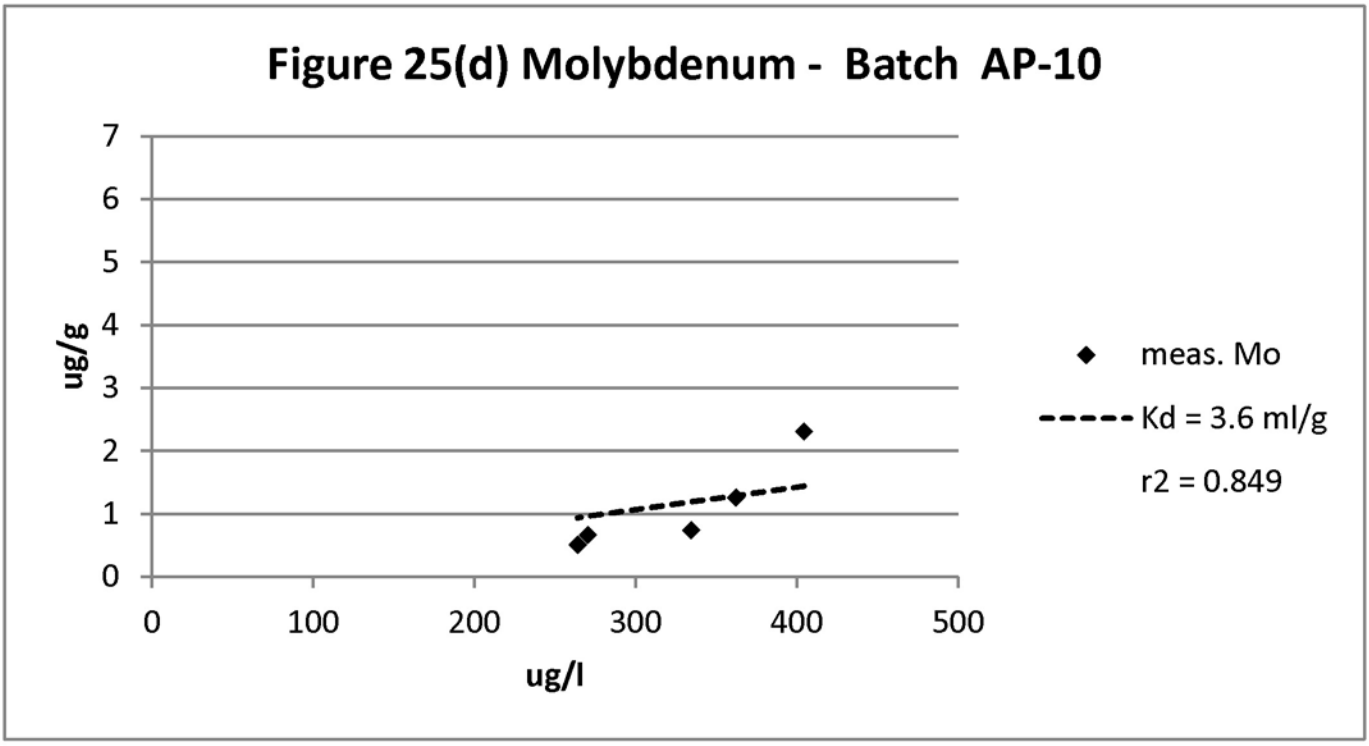


Figure 25(d) Molybdenum - Batch AP-10
7
6
5
4
3
2
1
0
ug/g
0
100
200
300
400
500
ug/l
meas. Mo
Kd = 3.6 ml/g
r2 = 0.849

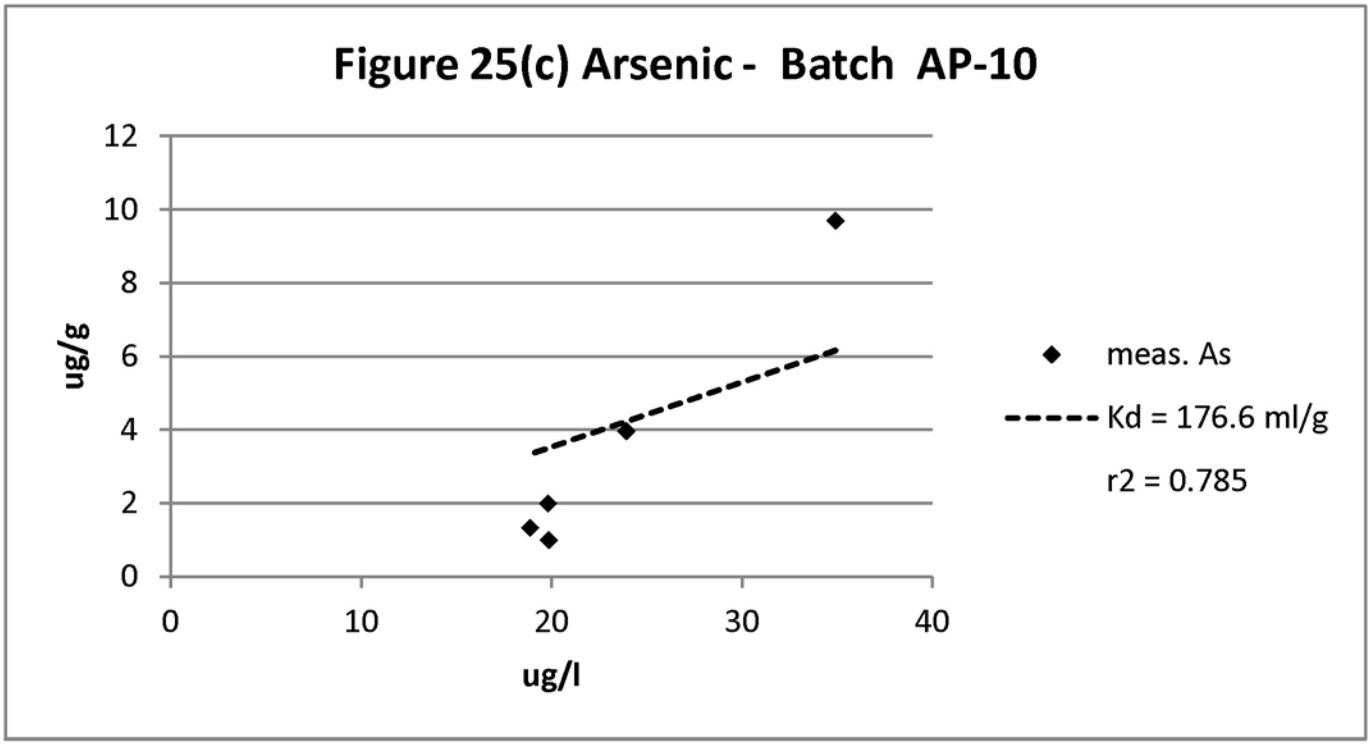


Figure 25(c) Arsenic - Batch AP-10
12
10
8
6
4
2
0
ug/g
0
10
20
30
40
ug/l
meas. As
Kd = 176.6 ml/g
r2 = 0.785

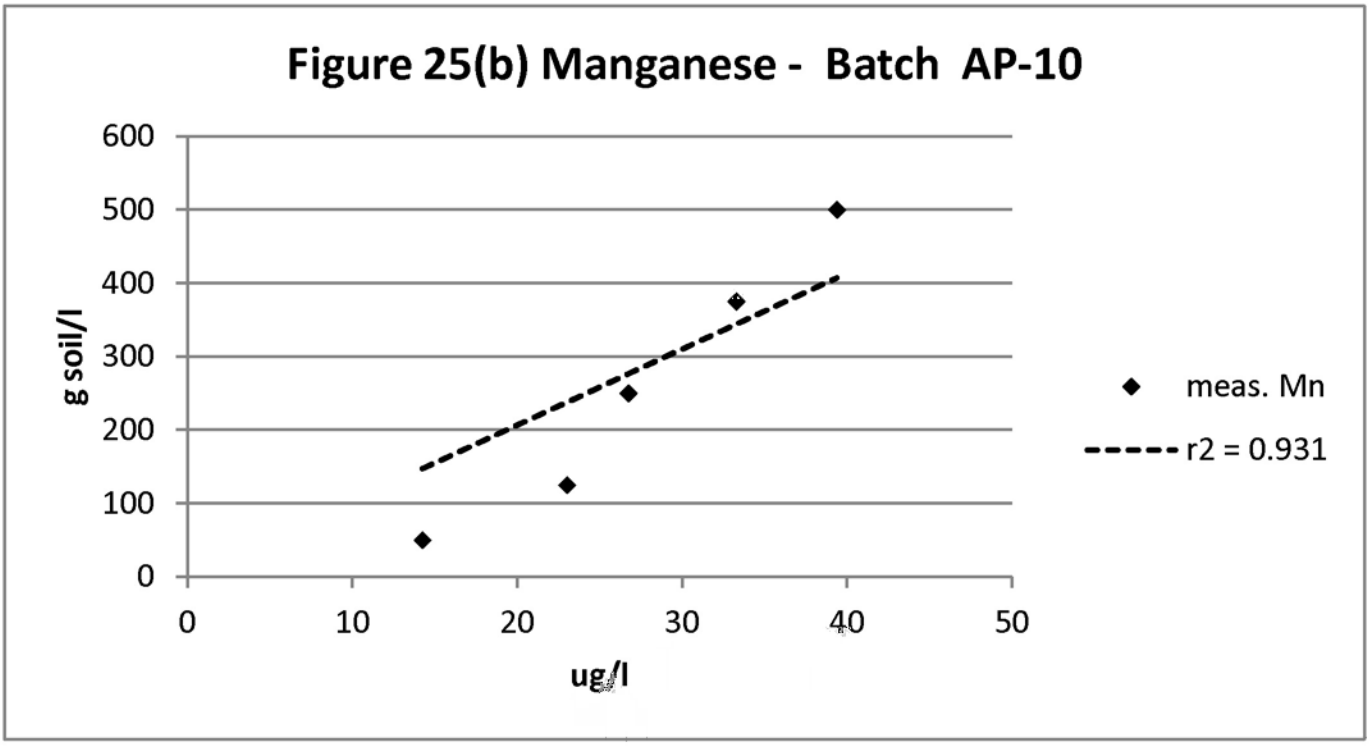


Figure 25(b) Manganese - Batch AP-10
600
500
400
300
200
100
0
g soil/l
0
10
20
30
40
50
ug/l
meas. Mn
r2 = 0.931

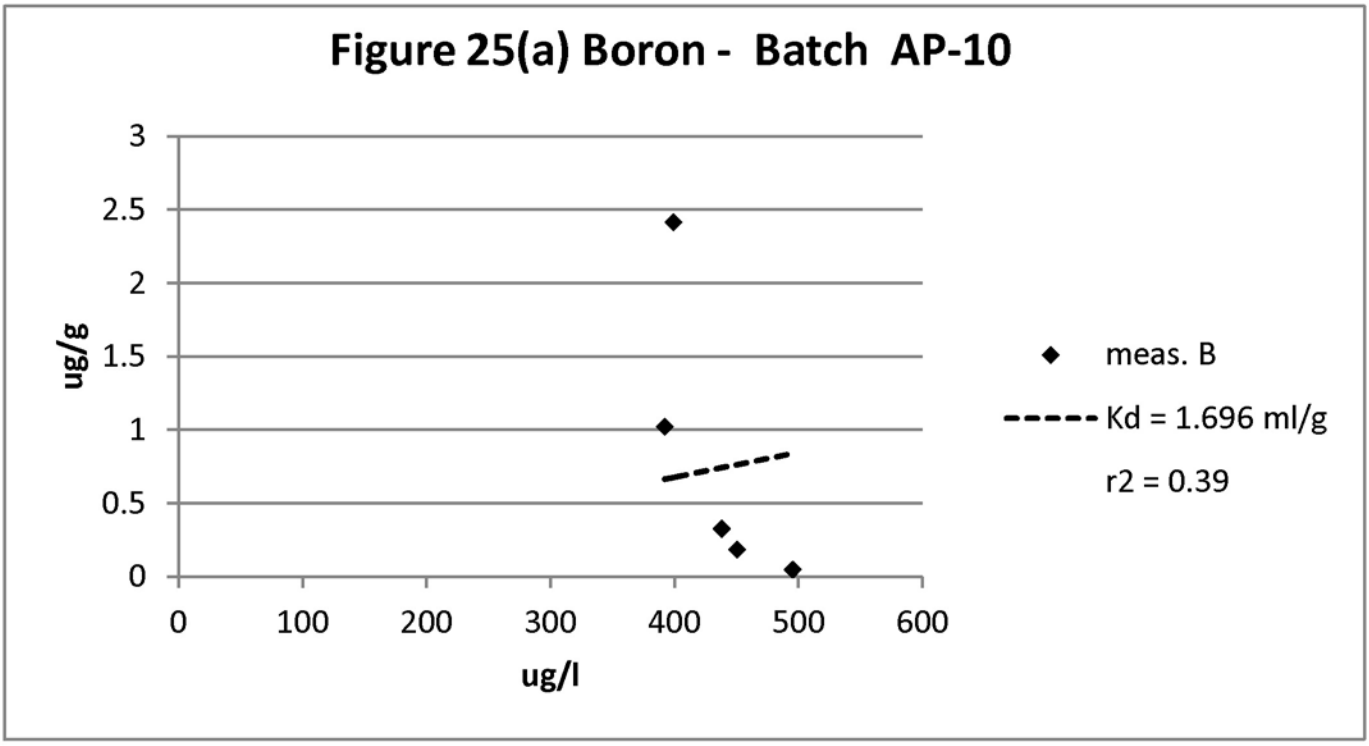


Figure 25(a) Boron - Batch AP-10
3
2.5
2
1.5
1
0.5
0
ug/g
0
100
200
300
400
500
600
ug/l
meas. B
Kd = 1.696 ml/g
r2 = 0.39

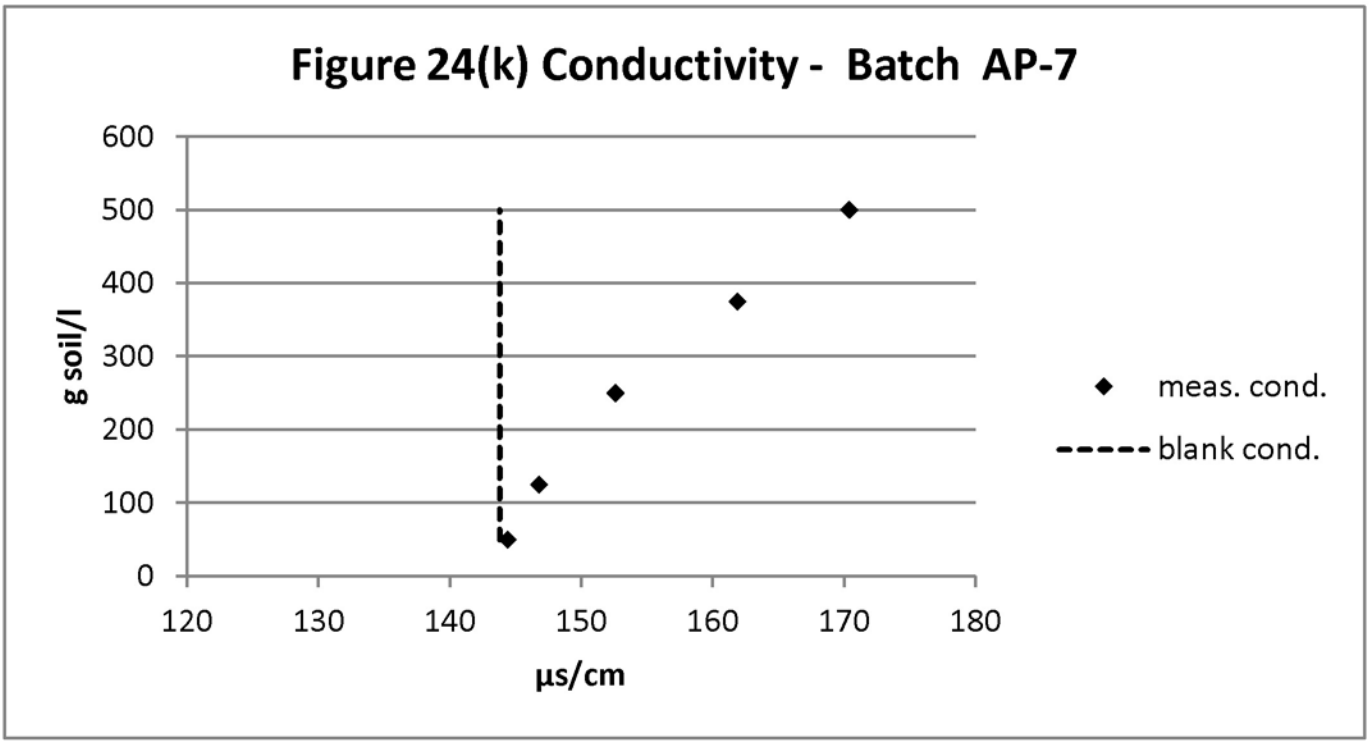


Figure 24(k) Conductivity - Batch AP-7
600
500
400
300
200
100
0
g soil/l
120
130
140
150
160
170
180
µs/cm
meas. cond.
blank cond.

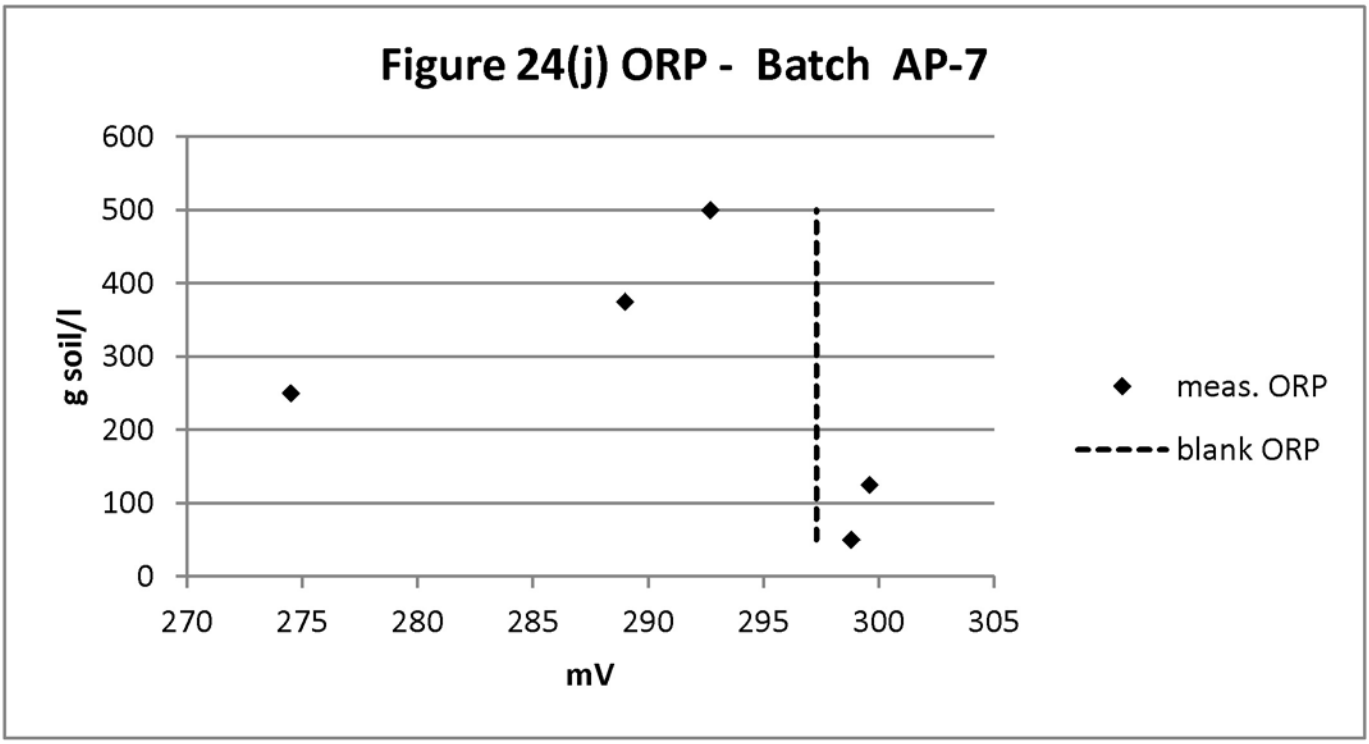


Figure 24(j) ORP - Batch AP-7
600
500
400
300
200
100
0
g soil/l
270
275
280
285
290
295
300
305
mV
meas. ORP
blank ORP

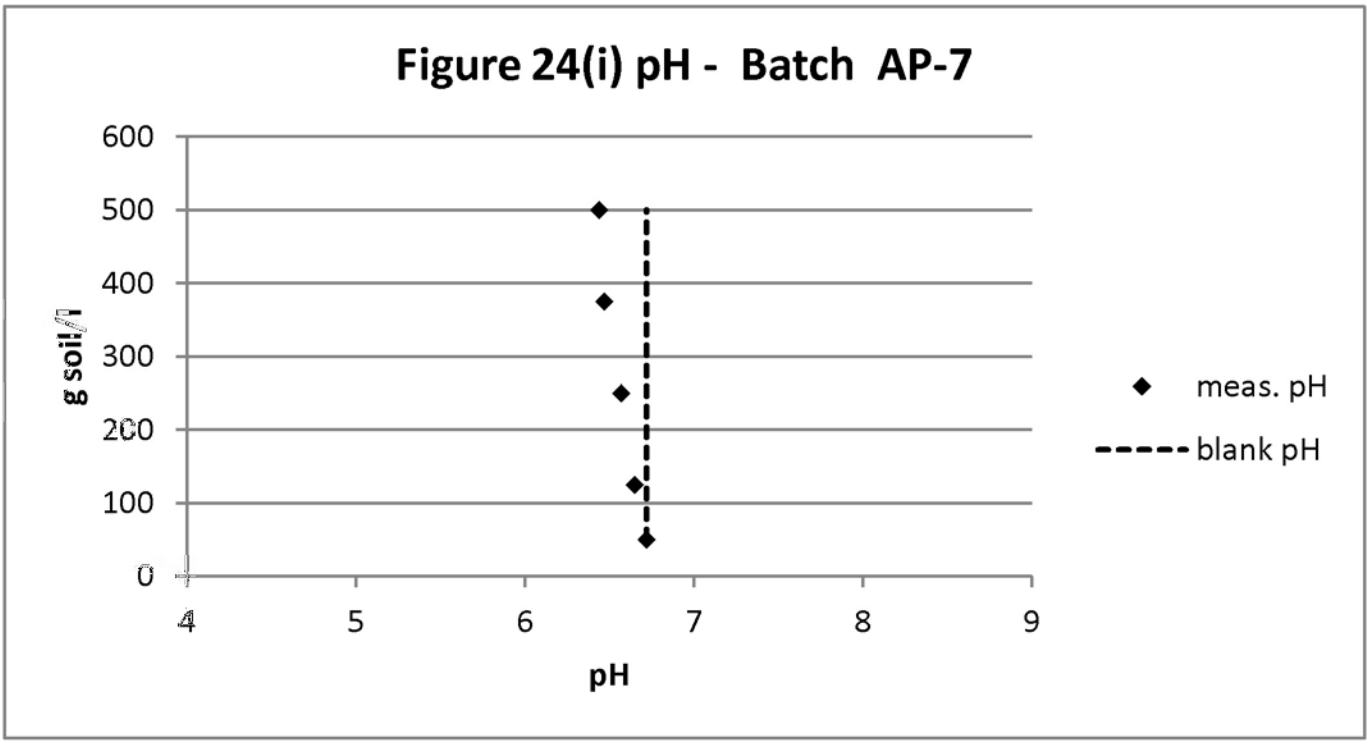


Figure 24(i) pH - Batch AP-7
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

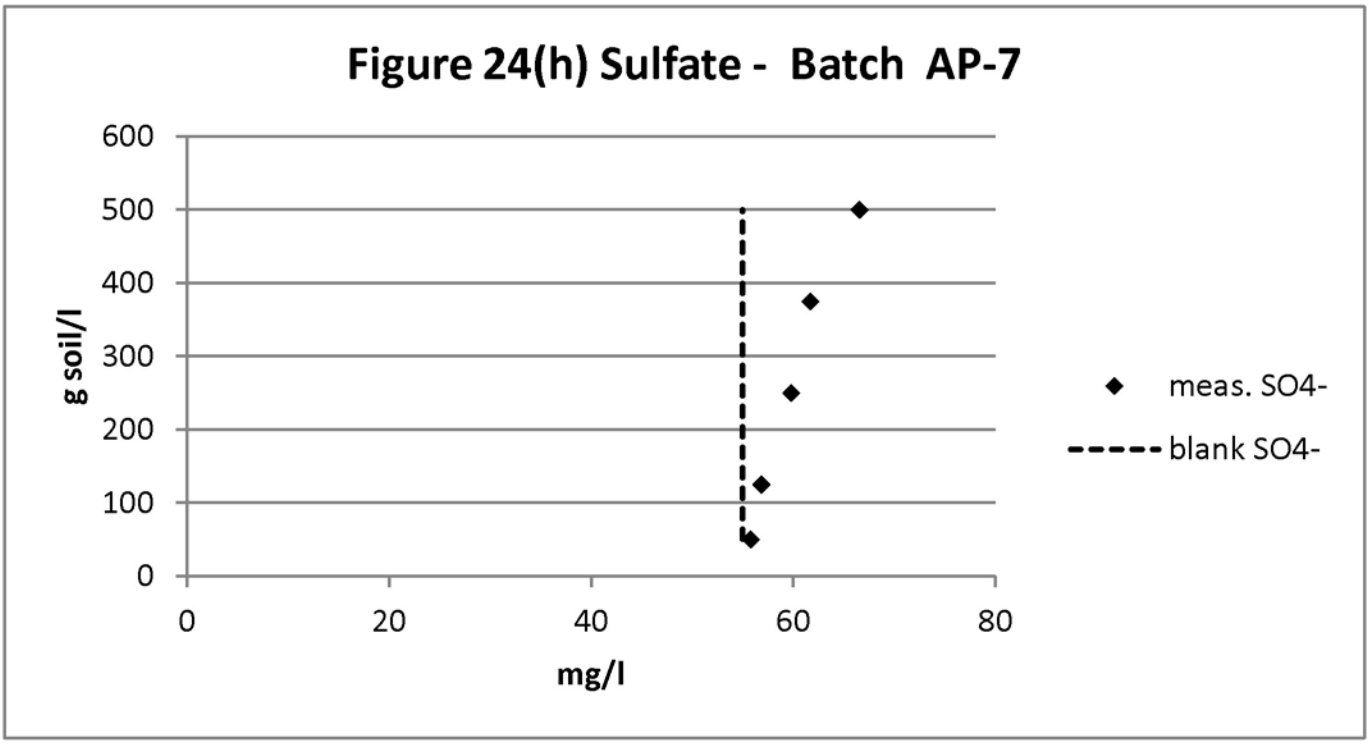


Figure 24(h) Sulfate - Batch AP-7
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

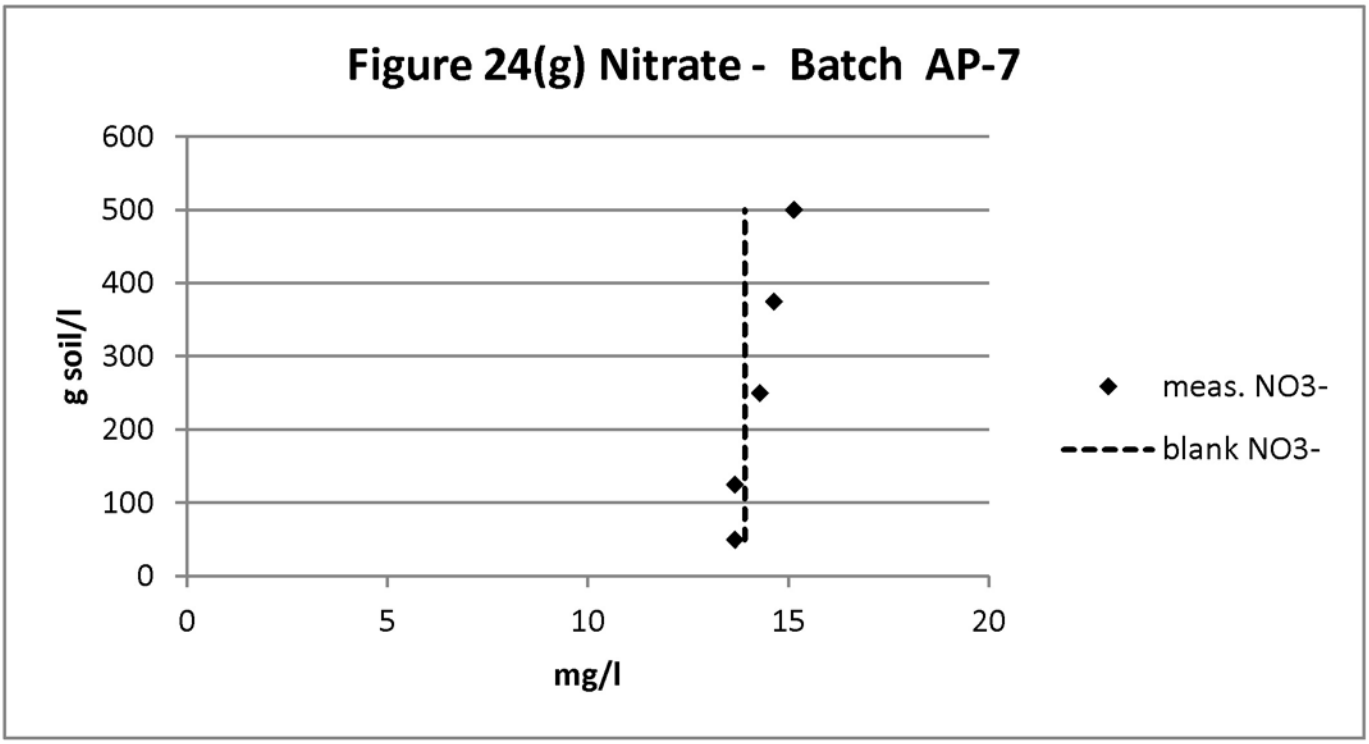


Figure 24(g) Nitrate - Batch AP-7
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

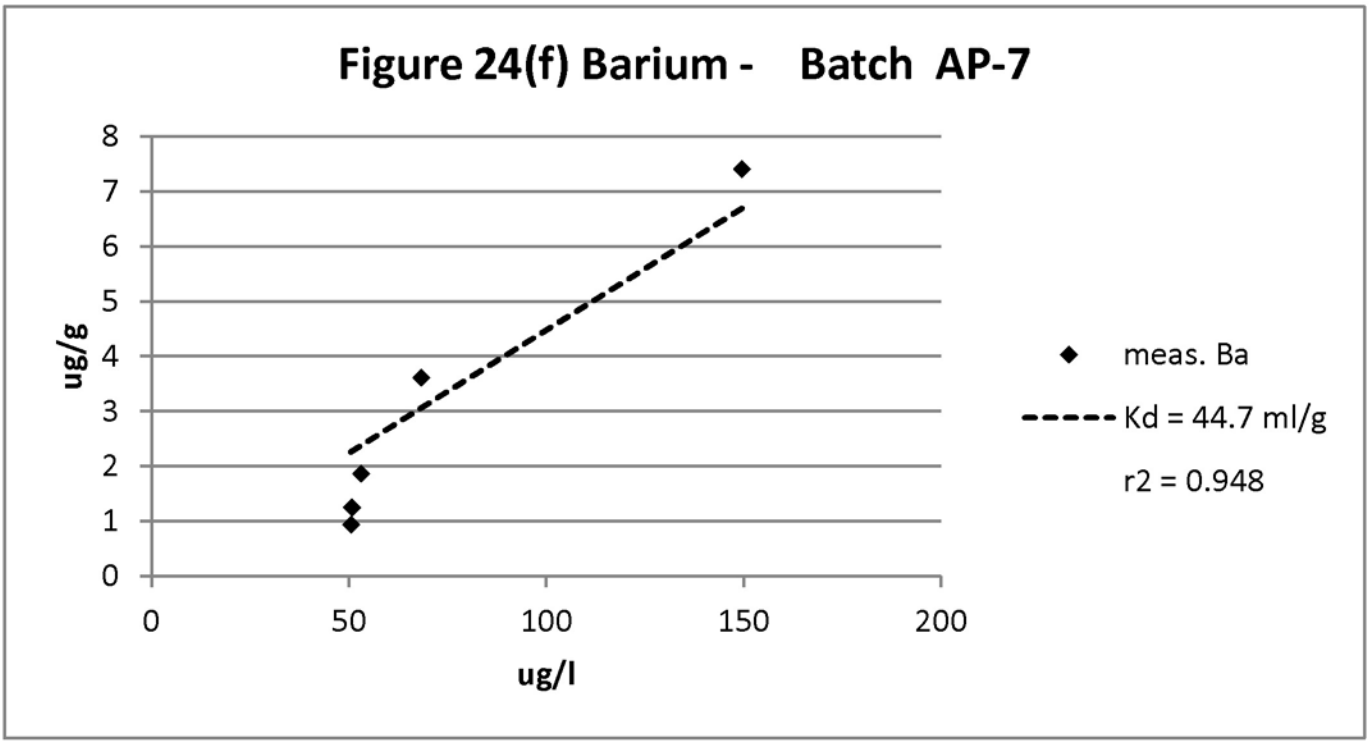


Figure 24(f) Barium - Batch AP-7
8
7
6
5
4
3
2
1
0
ug/g
0
50
100
150
200
ug/l
meas. Ba
Kd = 44.7 ml/g
r2 = 0.948

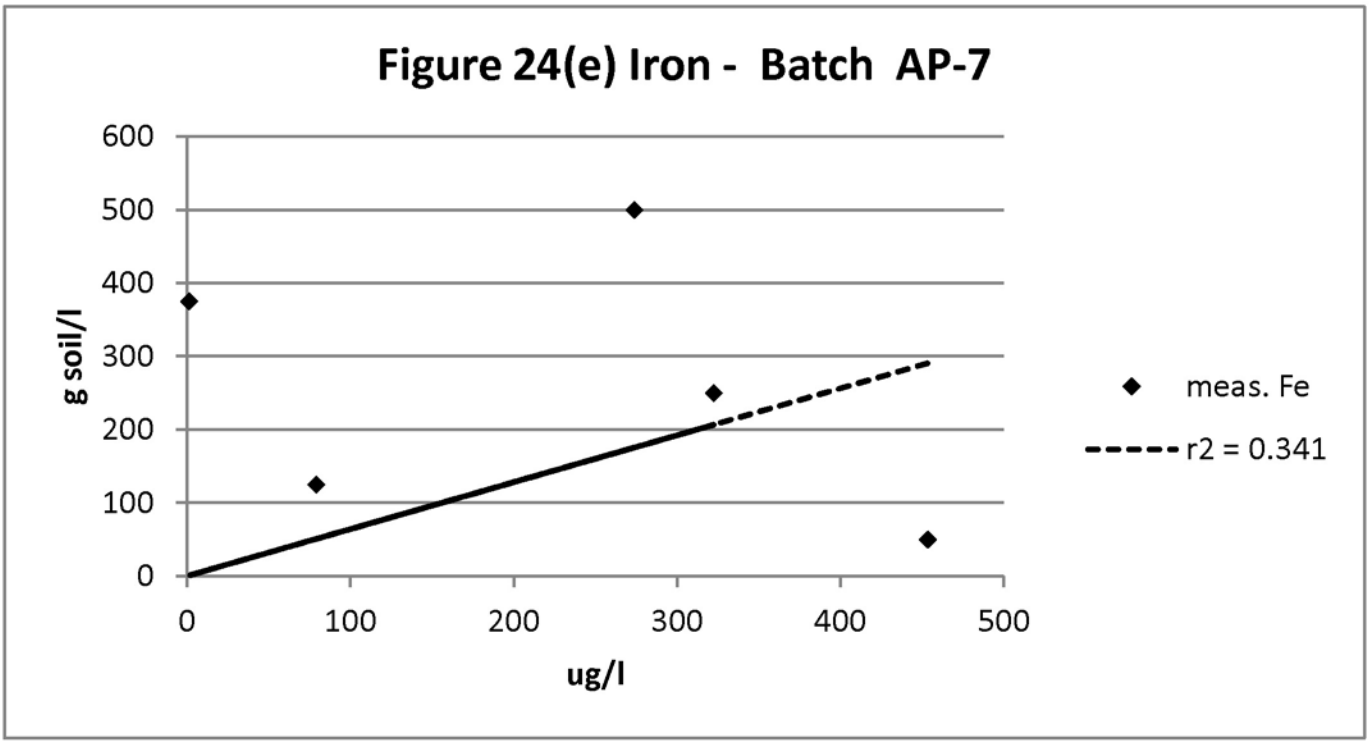


Figure 24(e) Iron - Batch AP-7
600
500
400
300
200
100
0
g soil/l
0
100
200
300
400
500
ug/l
meas. Fe
r2 = 0.341

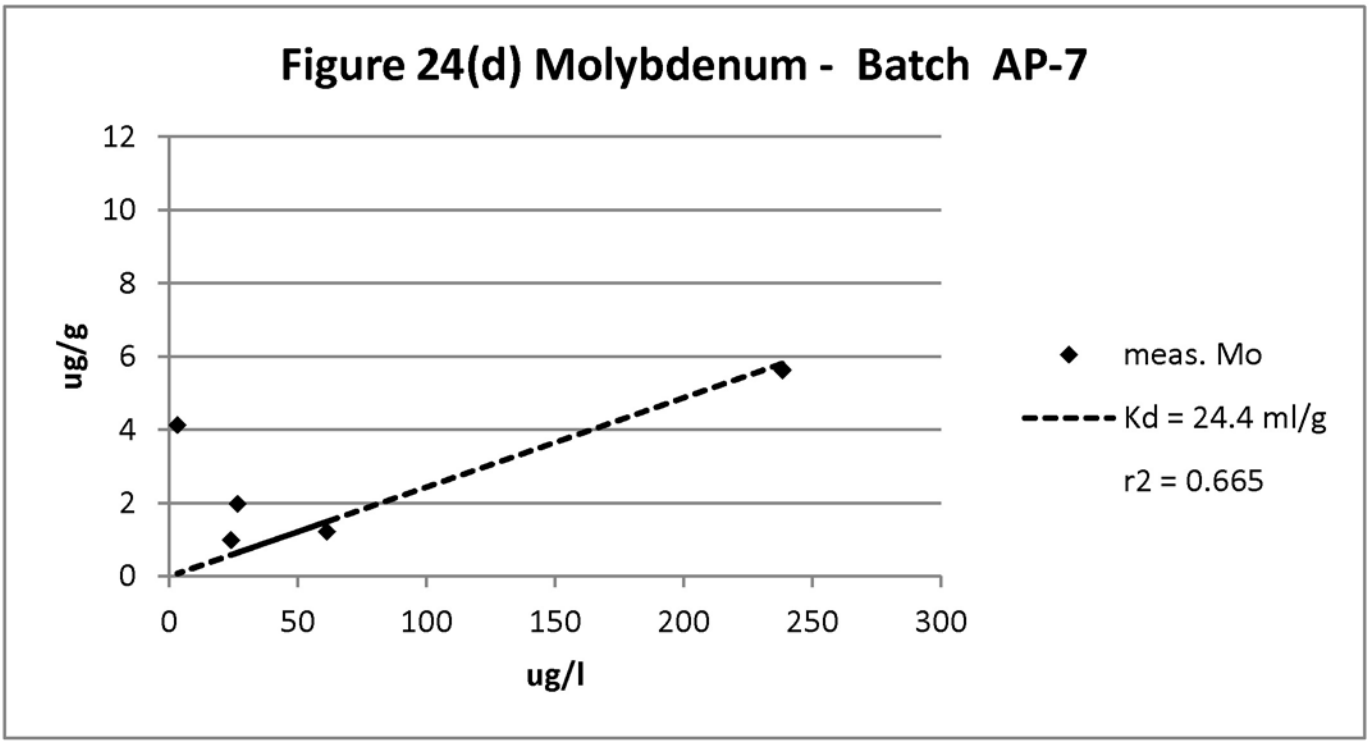


Figure 24(d) Molybdenum - Batch AP-7
12
10
8
6
4
2
0
ug/g
0
50
100
150
200
250
300
ug/l
meas. Mo
Kd = 24.4 ml/g
r2 = 0.665

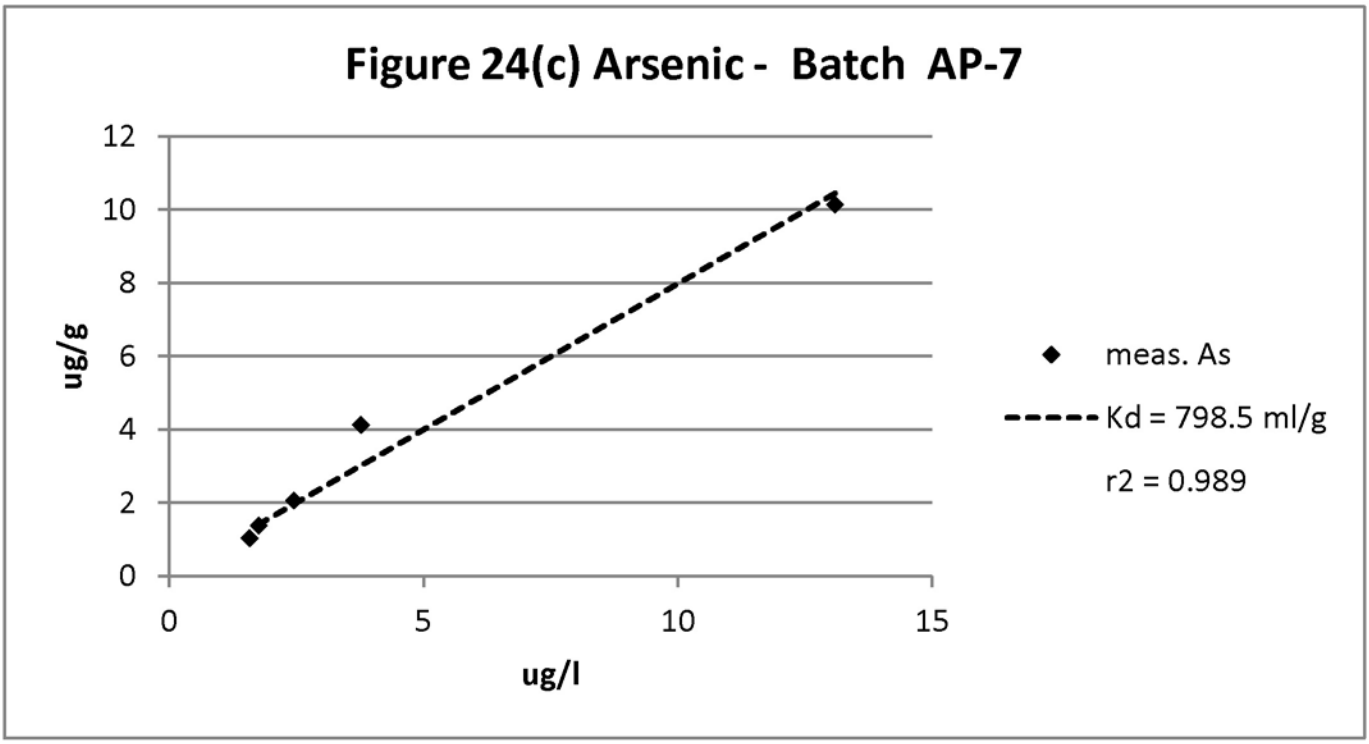


Figure 24(c) Arsenic - Batch AP-7
12
10
8
6
4
2
0
ug/g
0
5
10
15
ug/l
meas. As
Kd = 798.5 ml/g
r2 = 0.989

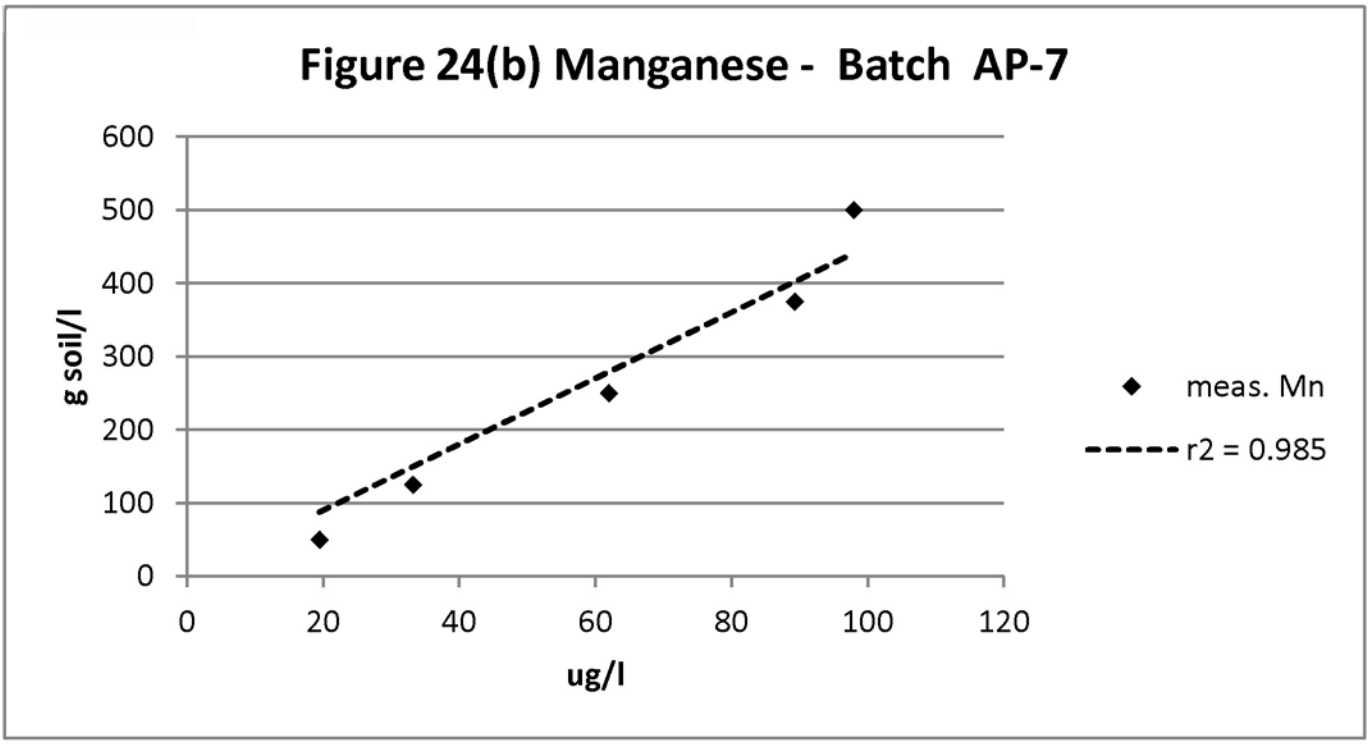


Figure 24(b) Manganese - Batch AP-7
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
100
120
ug/l
meas. Mn
r2 = 0.985

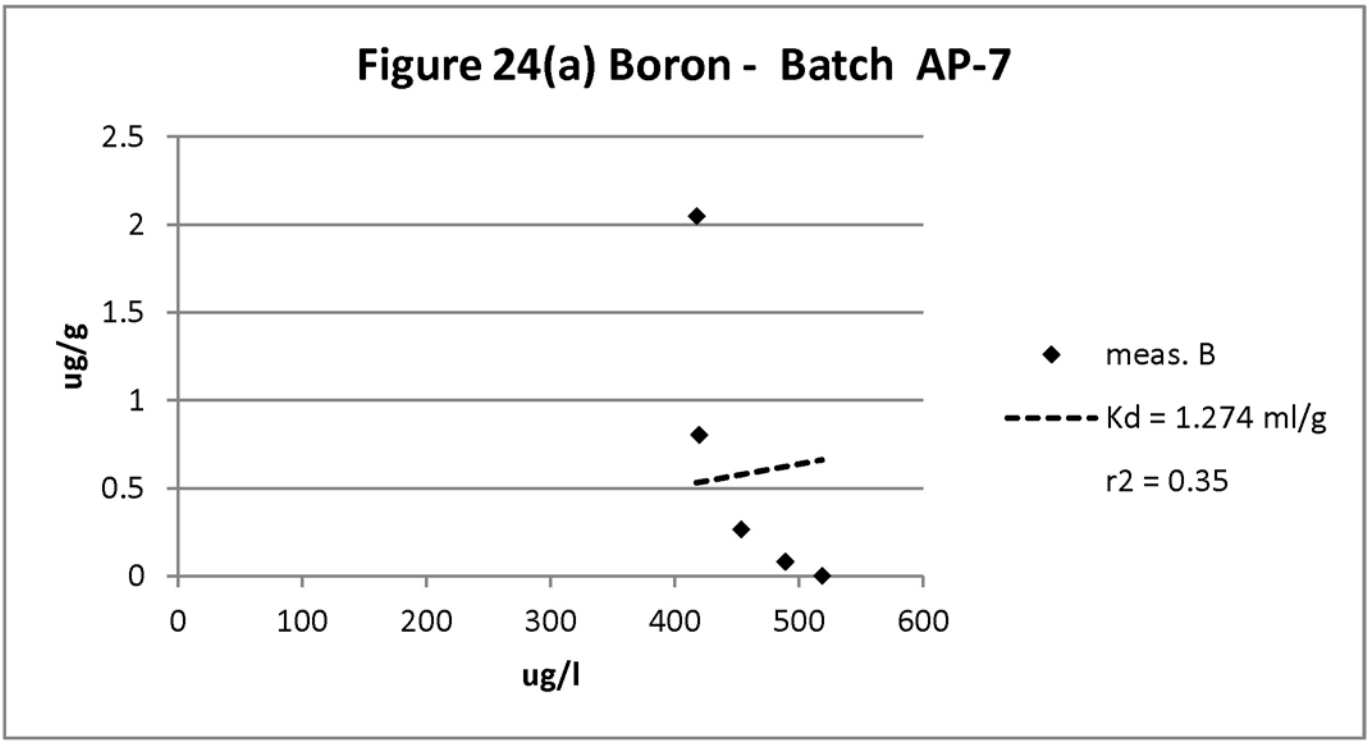


Figure 24(a) Boron - Batch AP-7
2.5
2
1.5
1
0.5
0
ug/g
0
100
200
300
400
500
600
ug/l
meas. B
Kd = 1.274 ml/g
r2 = 0.35

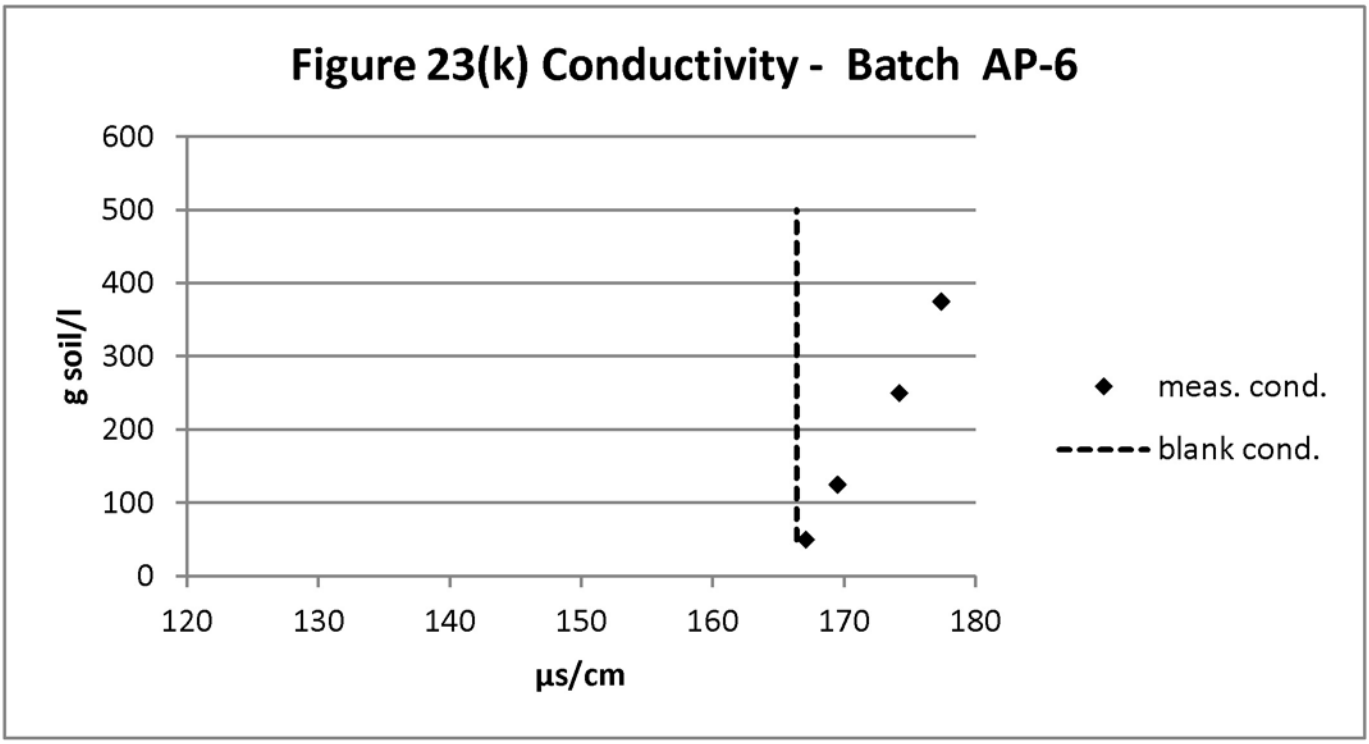


Figure 23(k) Conductivity - Batch AP-6
600
500
400
300
200
100
0
g soil/l
120
130
140
150
160
170
180
µs/cm
meas. cond.
blank cond.

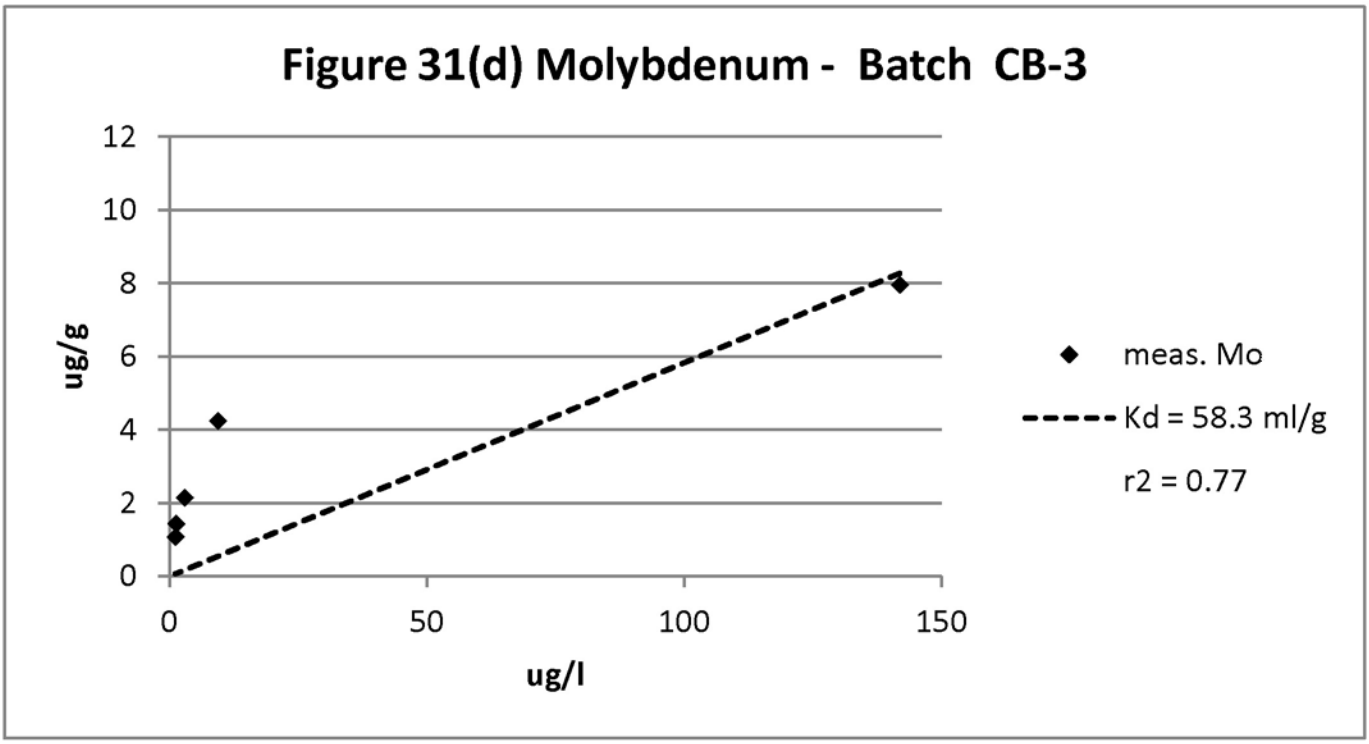


Figure 31(d) Molybdenum - Batch CB-3
12
10
8
6
4
2
0
ug/g
0
50
100
150
ug/l
meas. Mo
Kd = 58.3 ml/g
r2 = 0.77

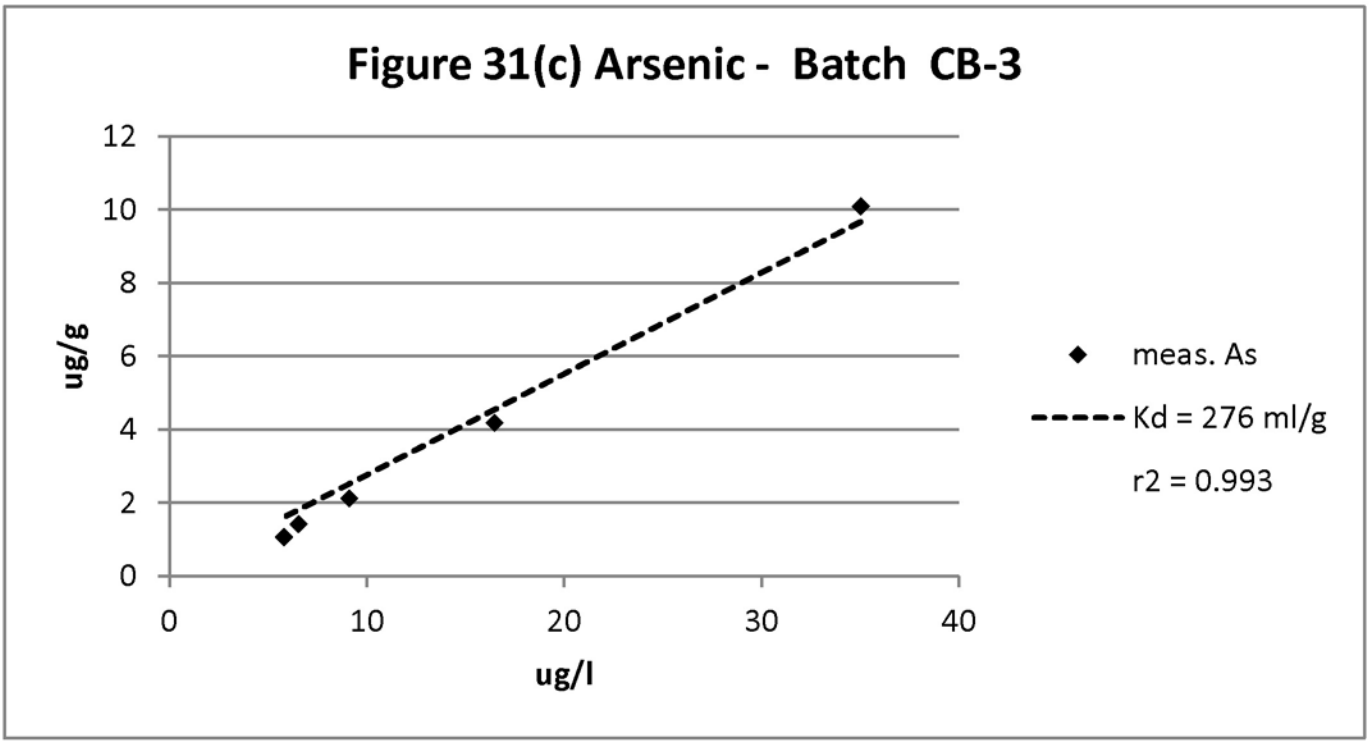


Figure 31(c) Arsenic - Batch CB-3
12
10
8
6
4
2
0
ug/g
0
10
20
30
40
ug/l
meas. As
Kd = 276 ml/g
r2 = 0.993

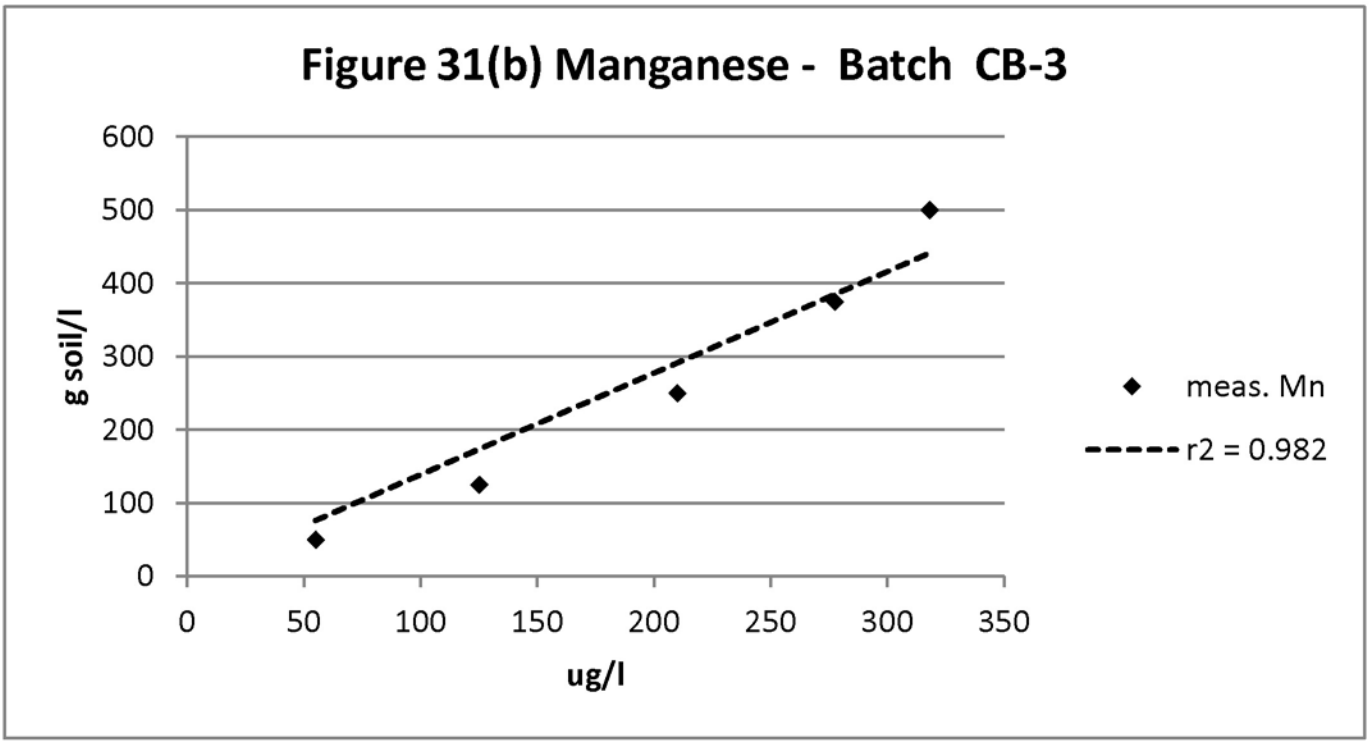


Figure 31(b) Manganese - Batch CB-3
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
250
300
350
ug/l
meas. Mn
r2 = 0.982

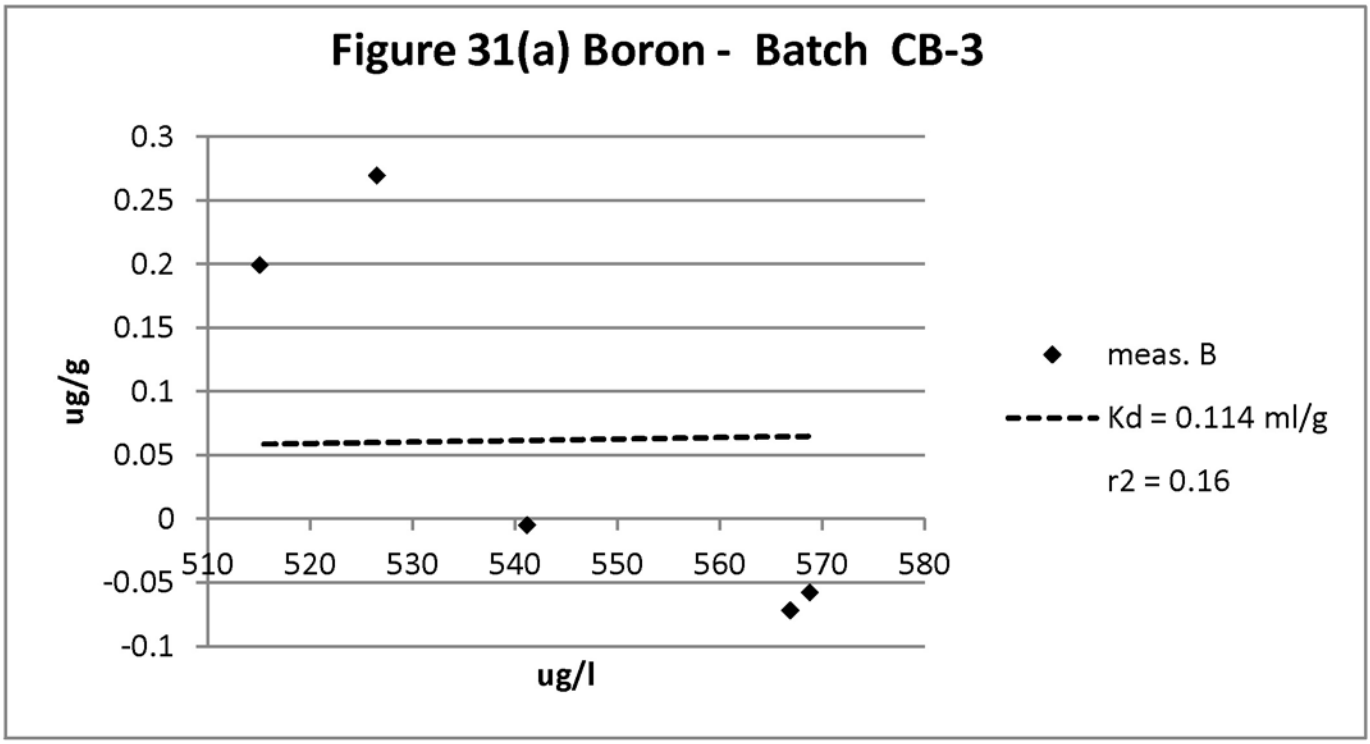


Figure 31(a) Boron - Batch CB-3
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
ug/g
510
520
530
540
550
560
570
580
ug/l
meas. B
Kd = 0.114 ml/g
r2 = 0.16

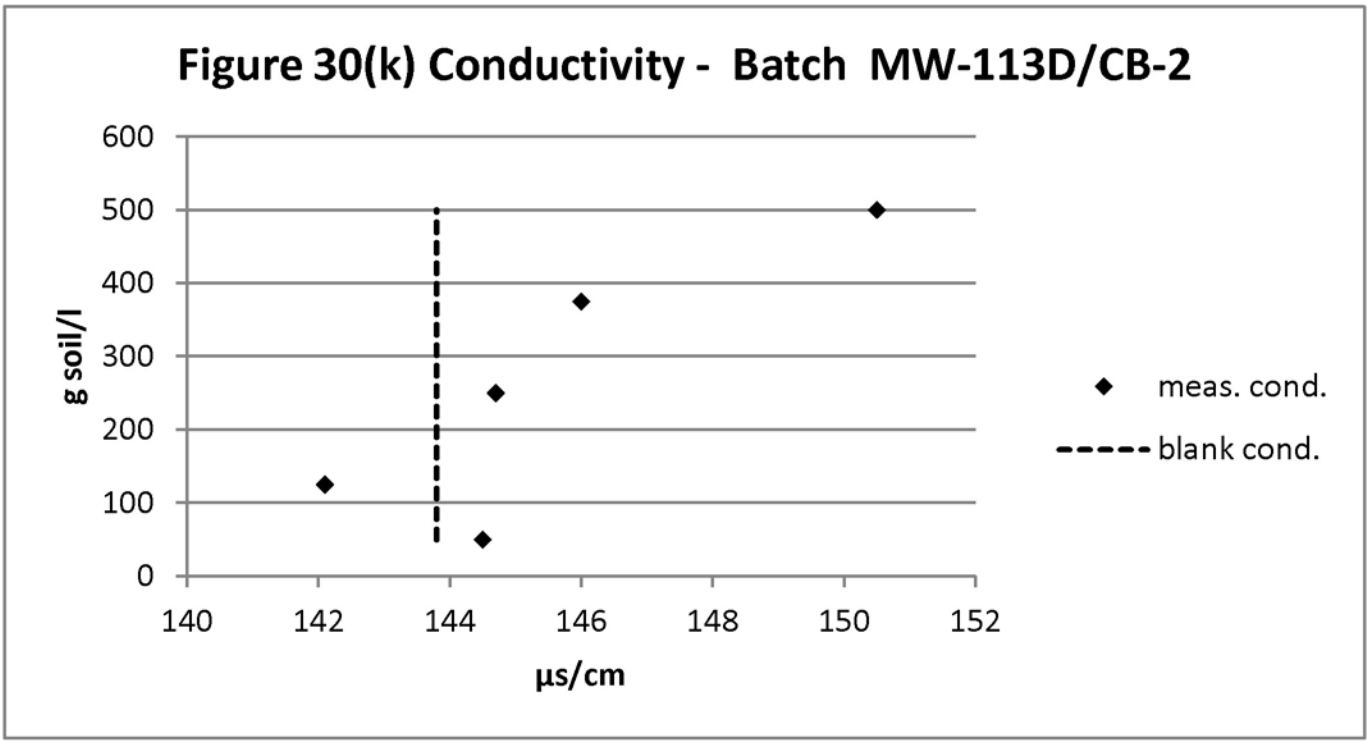


Figure 30(k) Conductivity - Batch MW-113D/CB-2
600
500
400
300
200
100
0
g soil/l
140
142
144
146
148
150
152
µs/cm
meas. cond.
blank cond.

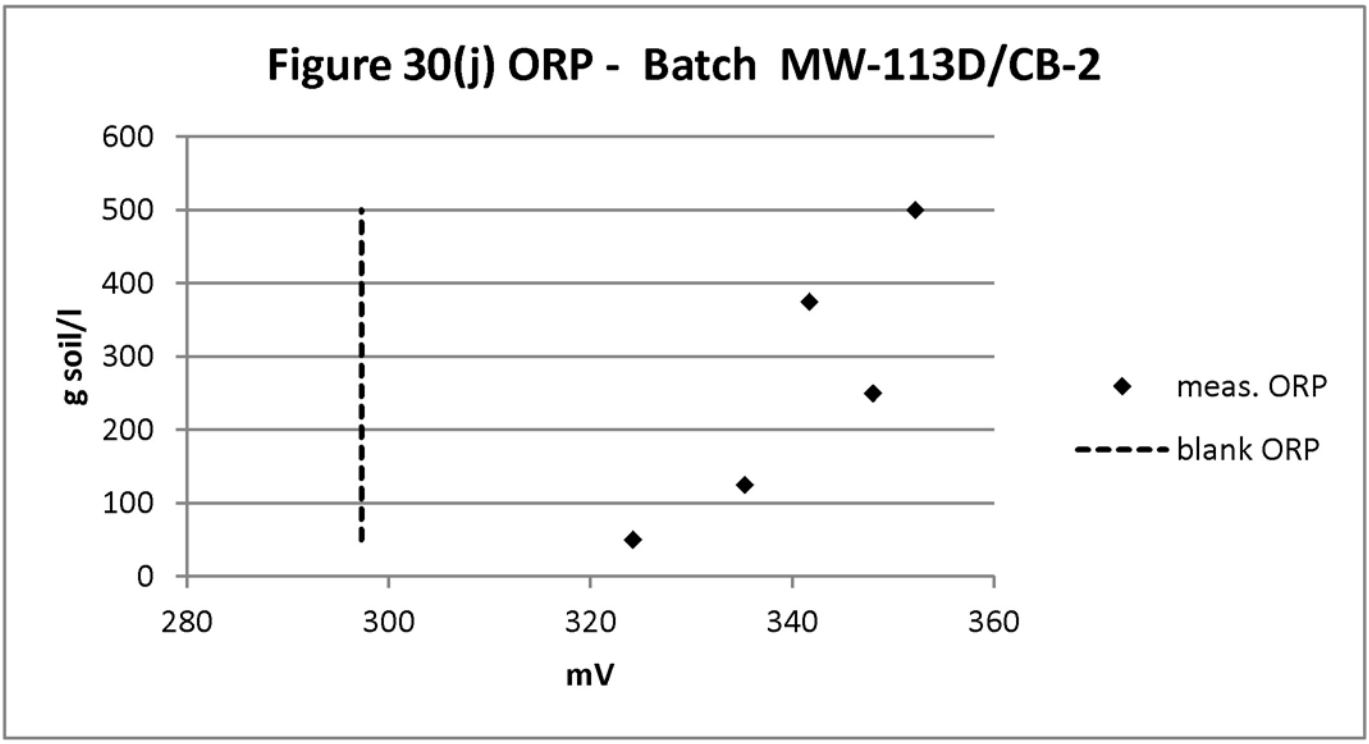


Figure 30(j) ORP - Batch MW-113D/CB-2
600
500
400
300
200
100
0
g soil/l
280
300
320
340
360
mV
meas. ORP
blank ORP

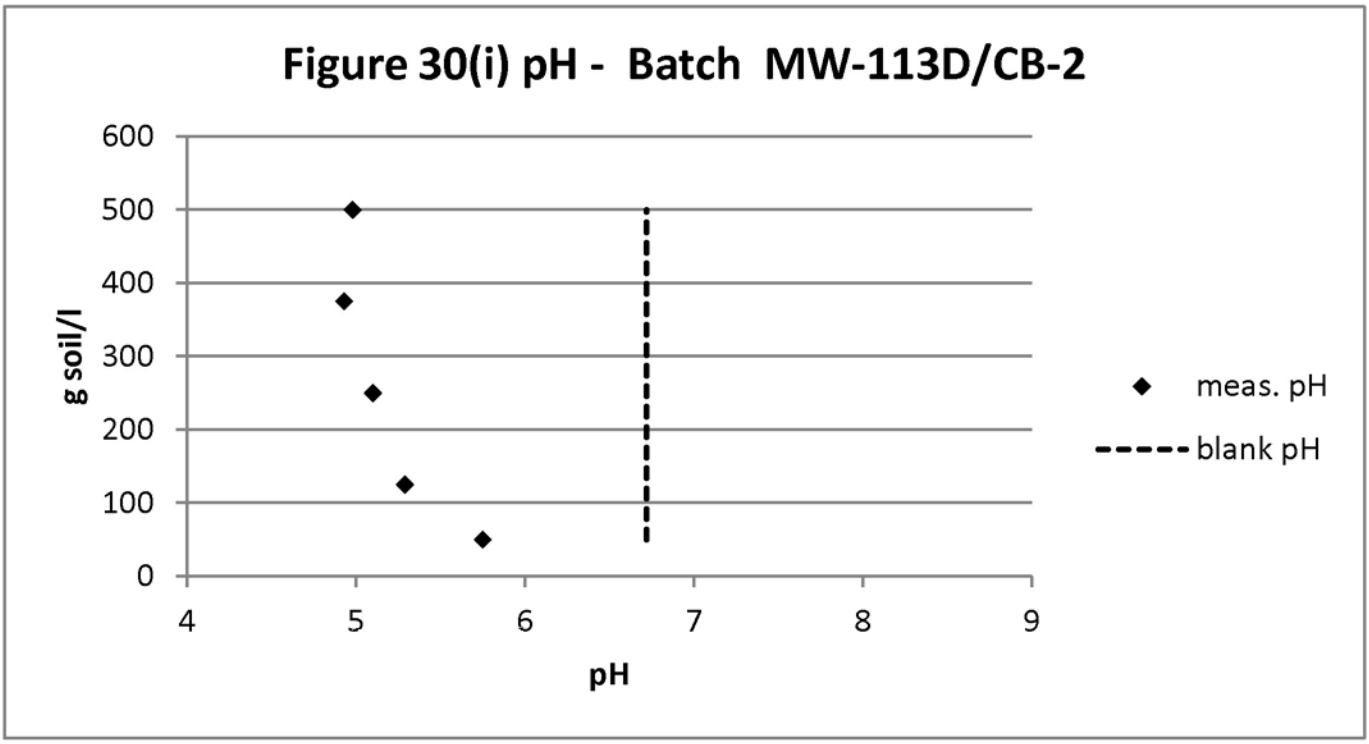


Figure 30(i) pH - Batch MW-113D/CB-2
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

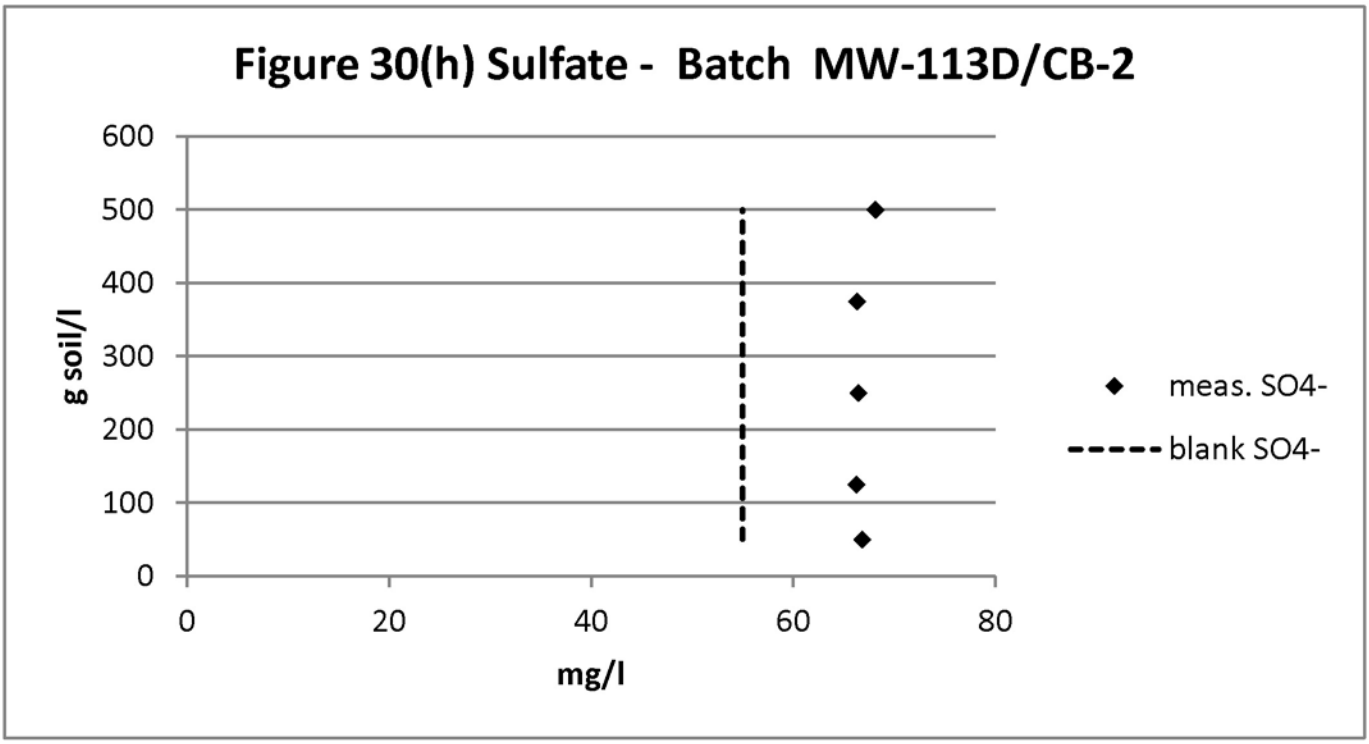


Figure 30(h) Sulfate - Batch MW-113D/CB-2
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

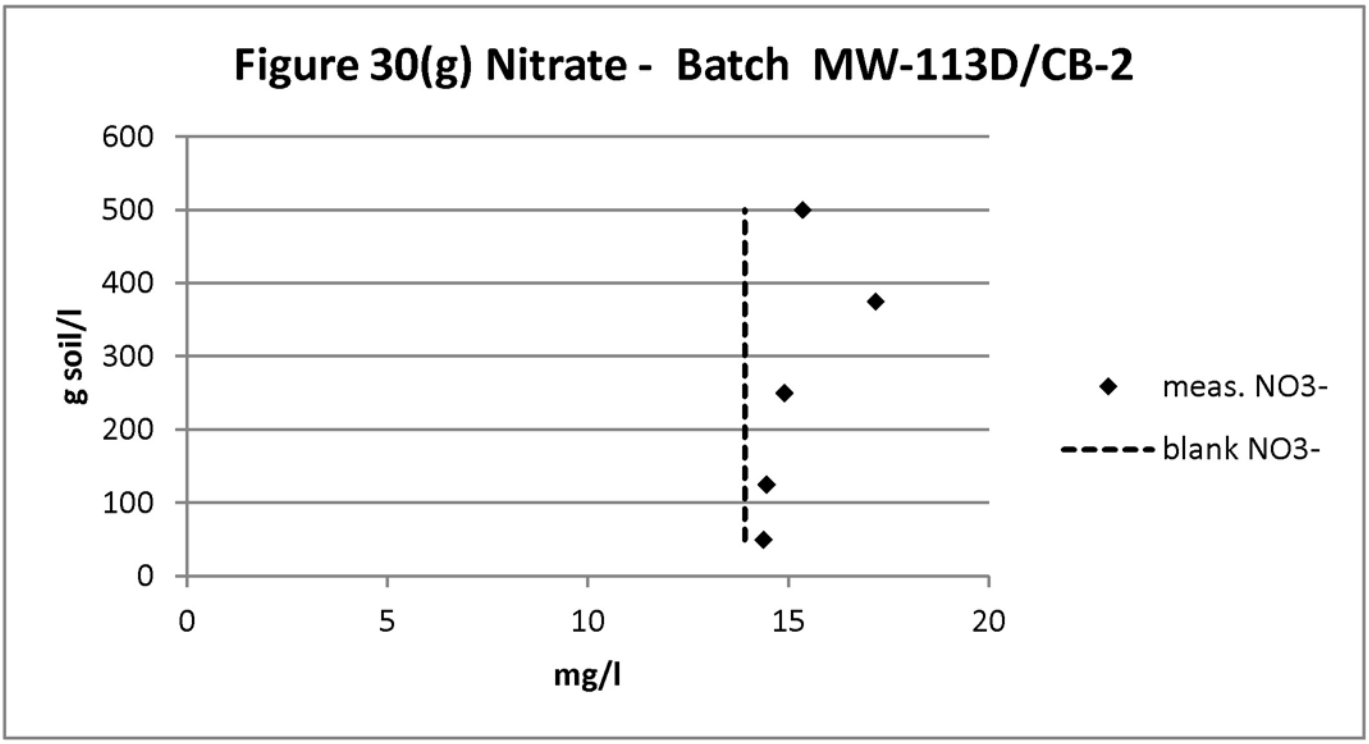


Figure 30(g) Nitrate - Batch MW-113D/CB-2
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

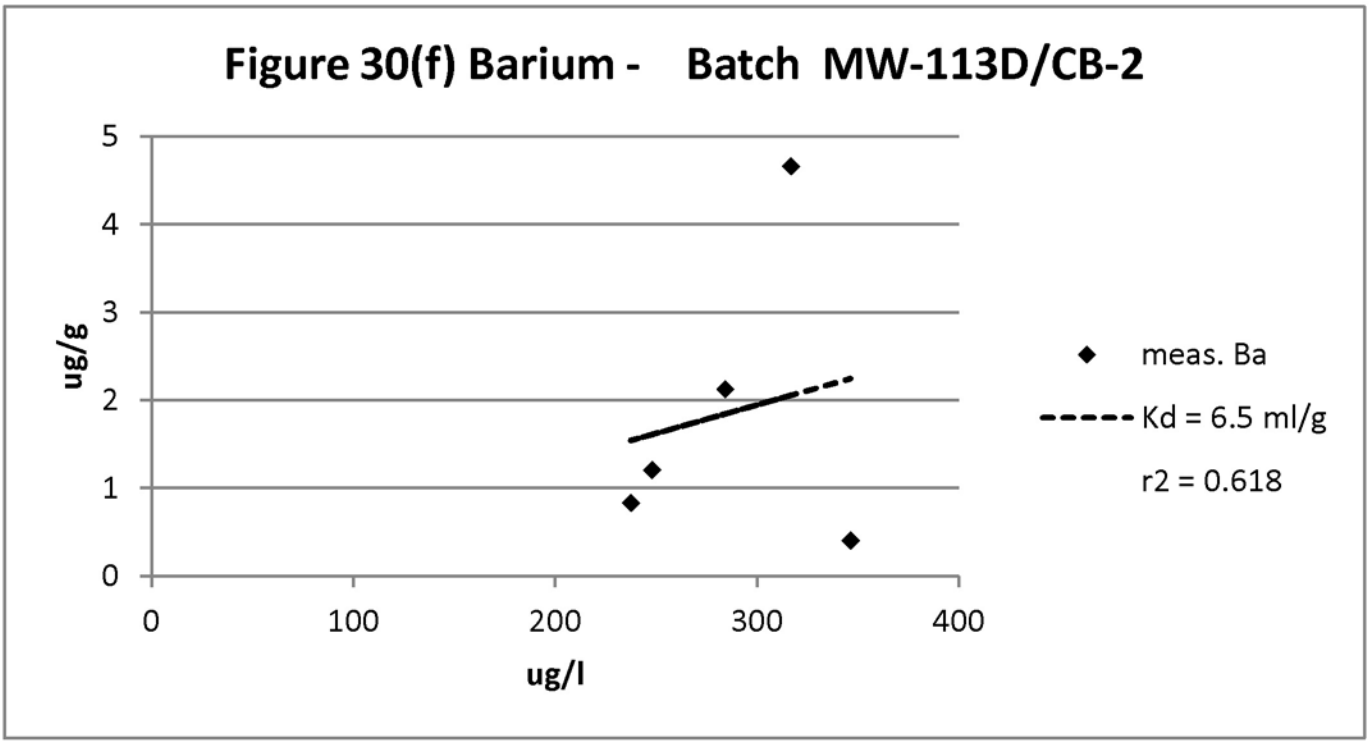


Figure 30(f) Barium - Batch MW-113D/CB-2
5
4
3
2
1
0
ug/g
0
100
200
300
400
ug/l
meas. Ba
Kd = 6.5 ml/g
r2 = 0.618

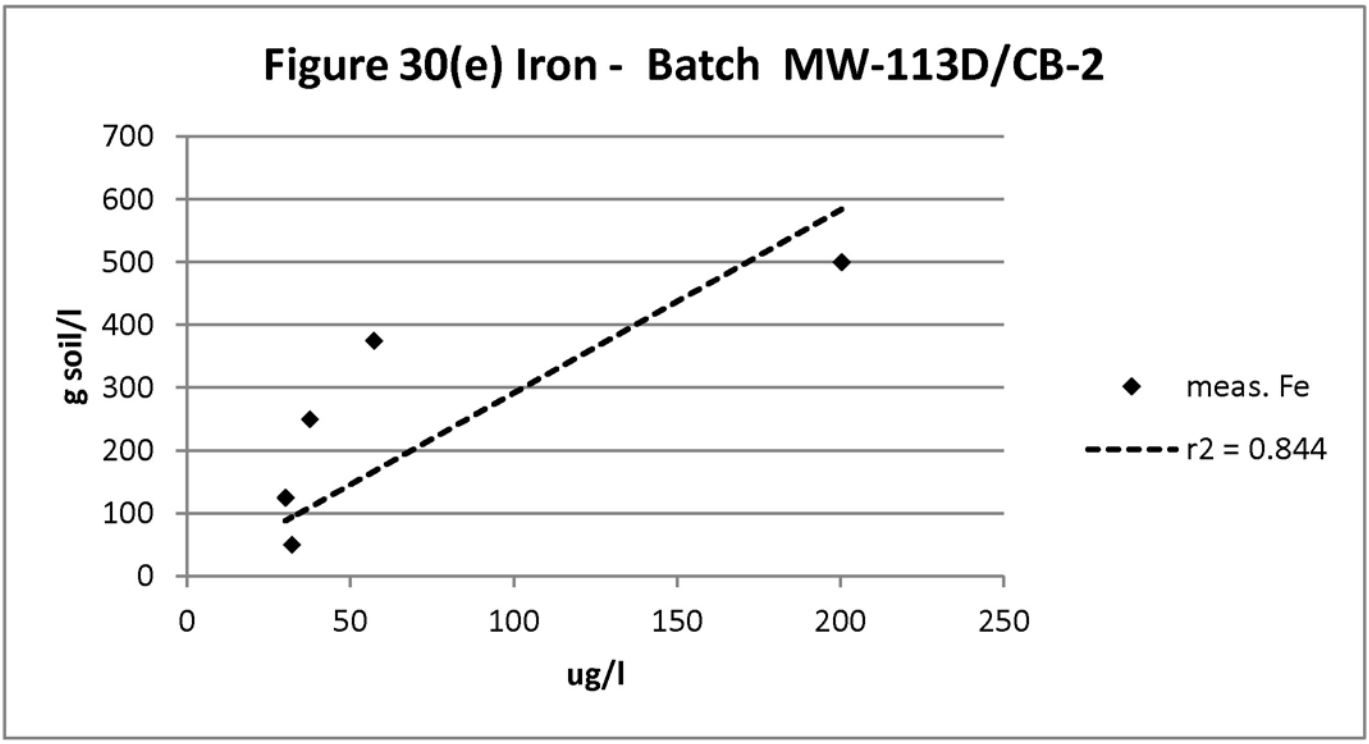


Figure 30(e) Iron - Batch MW-113D/CB-2
700
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
250
ug/l
meas. Fe
r2 = 0.844

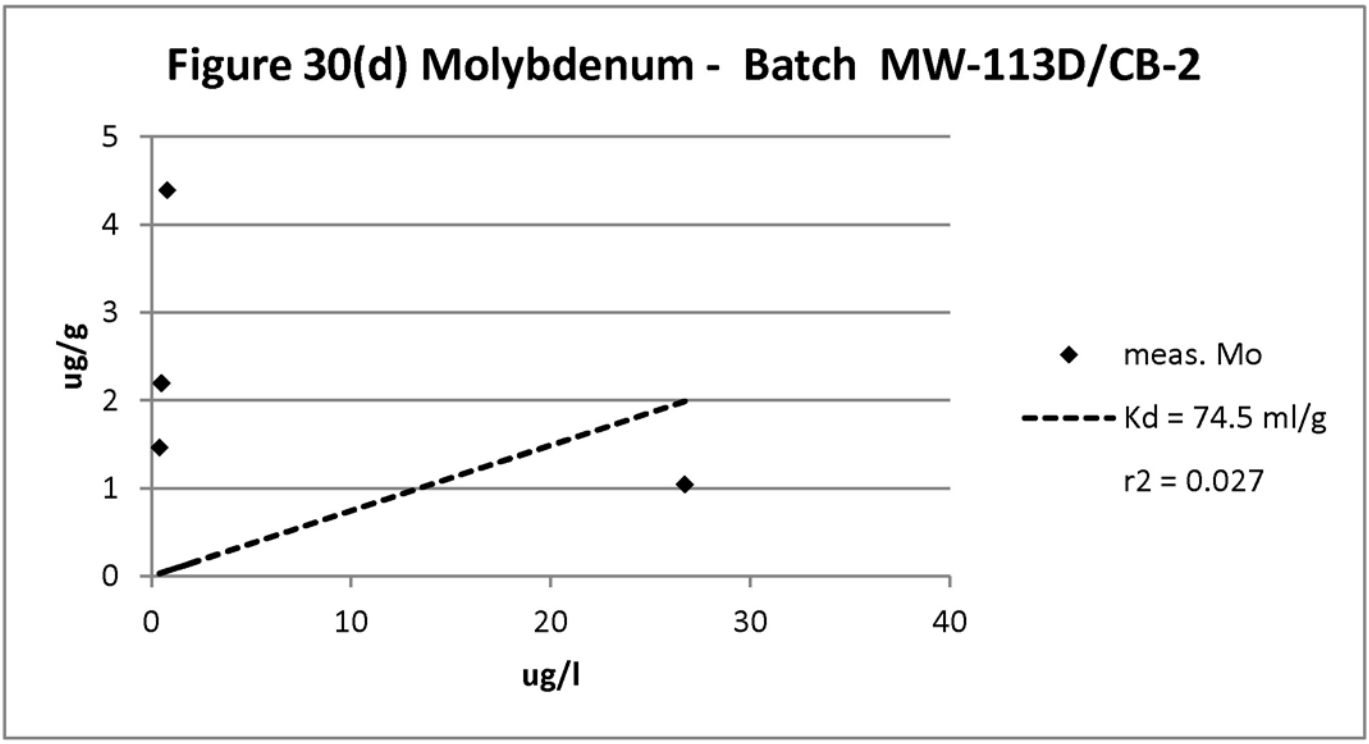


Figure 30(d) Molybdenum - Batch MW-113D/CB-2
5
4
3
2
1
0
ug/g
0
10
20
30
40
ug/l
meas. Mo
Kd = 74.5 ml/g
r2 = 0.027

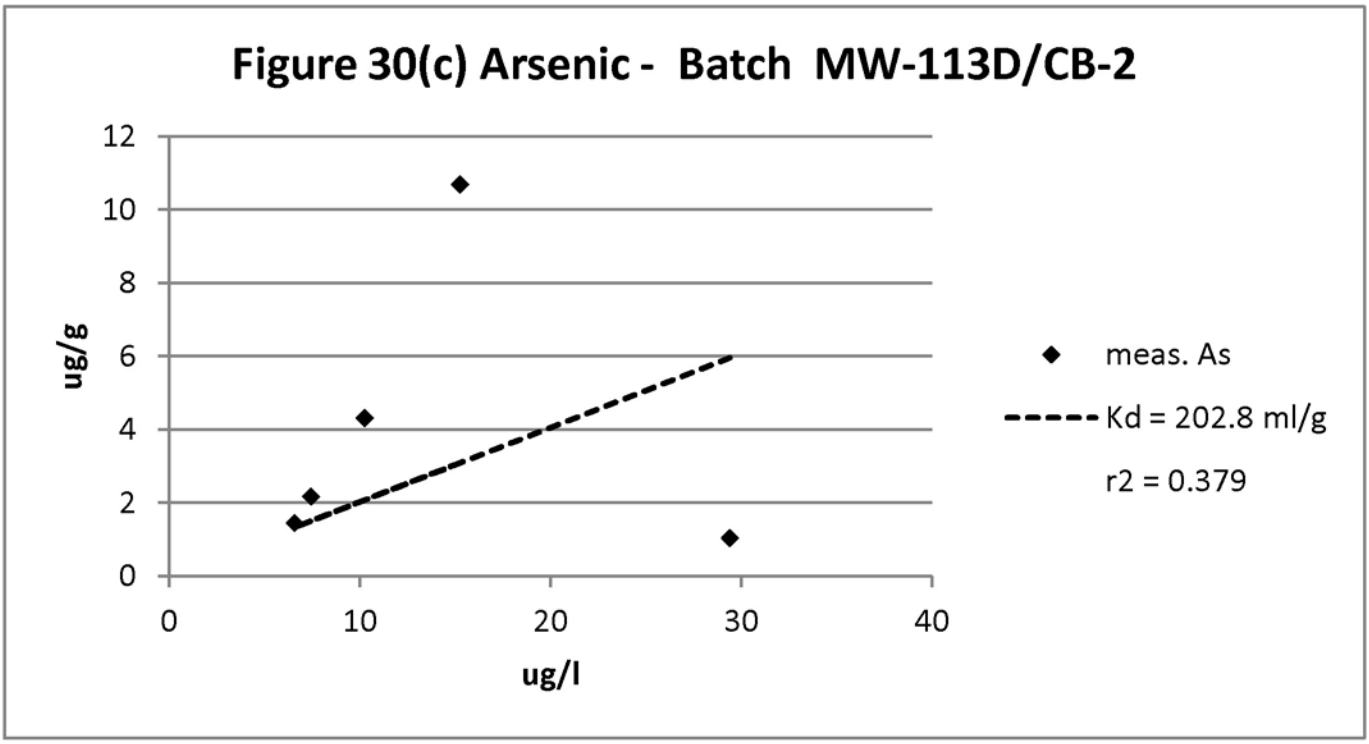


Figure 30(c) Arsenic - Batch MW-113D/CB-2
12
10
8
6
4
2
0
ug/g
0
10
20
30
40
ug/l
meas. As
Kd = 202.8 ml/g
r2 = 0.379

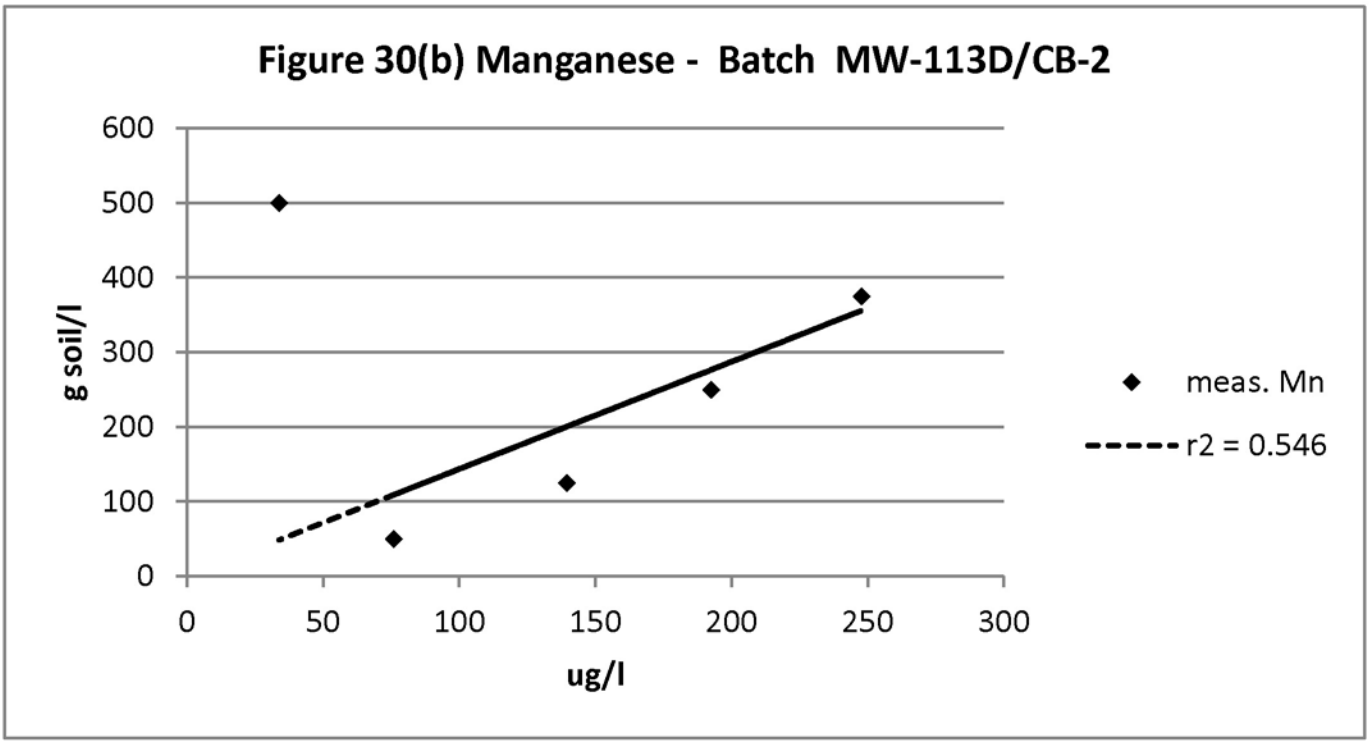


Figure 30(b) Manganese - Batch MW-113D/CB-2
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
250
300
ug/l
meas. Mn
r2 = 0.546

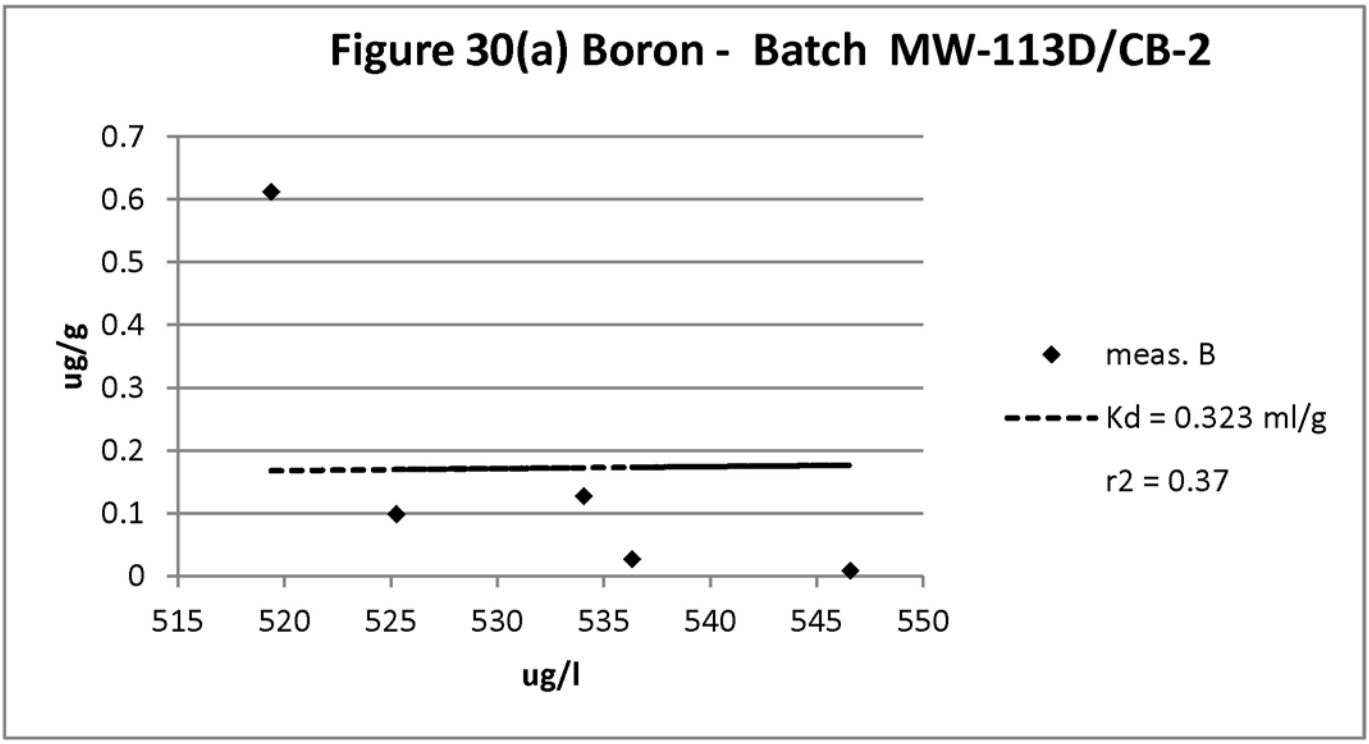


Figure 30(a) Boron - Batch MW-113D/CB-2
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ug/g
515
520
525
530
535
540
545
550
ug/l
meas. B
Kd = 0.323 ml/g
r2 = 0.37

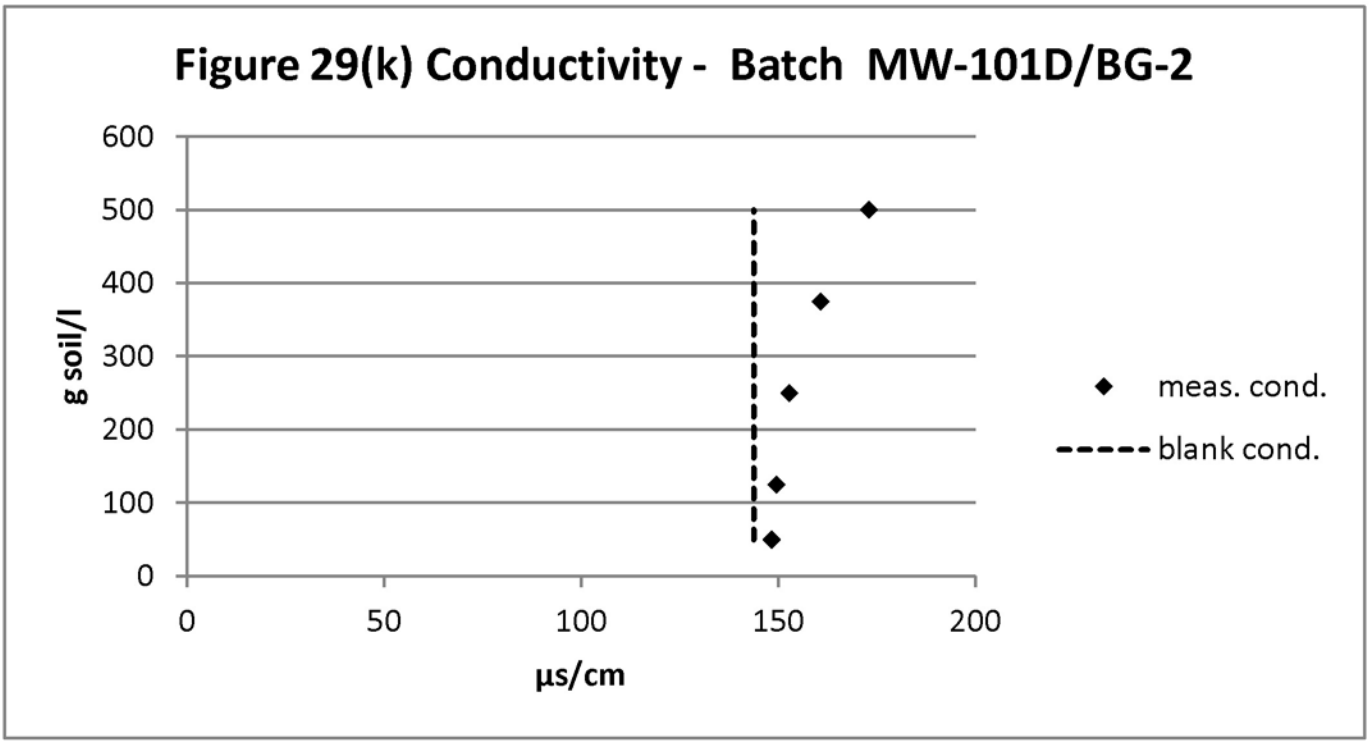


Figure 29(k) Conductivity - Batch MW-101D/BG-2
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
µs/cm
meas. cond.
blank cond.

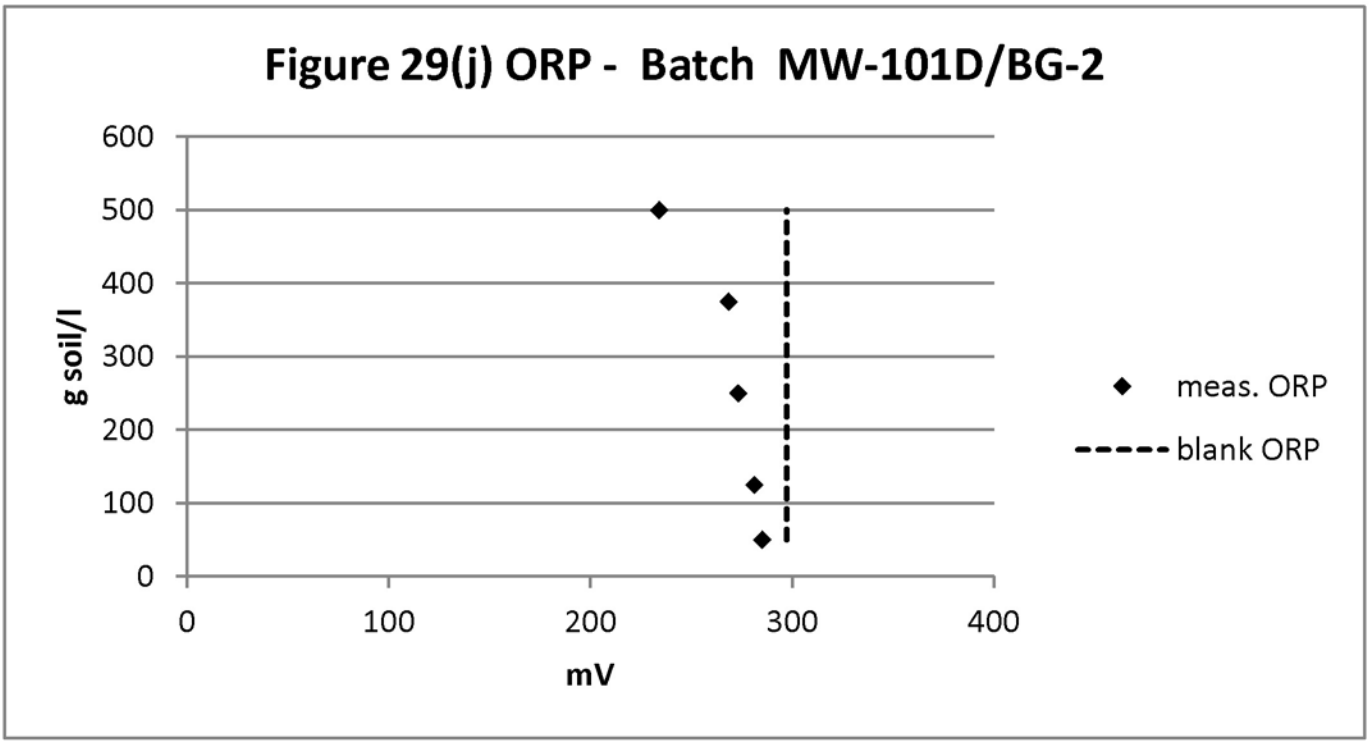


Figure 29(j) ORP - Batch MW-101D/BG-2
600
500
400
300
200
100
0
g soil/l
0
100
200
300
400
mV
meas. ORP
blank ORP

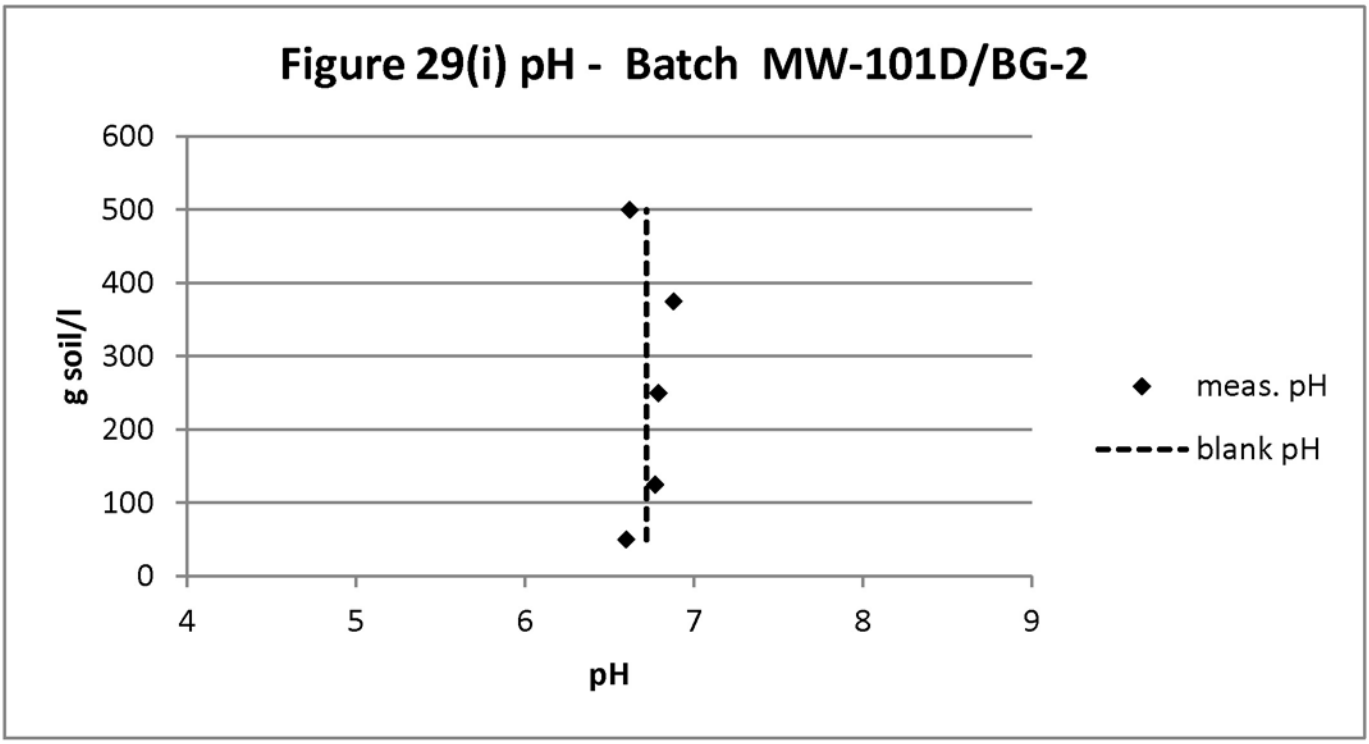


Figure 29(i) pH - Batch MW-101D/BG-2
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

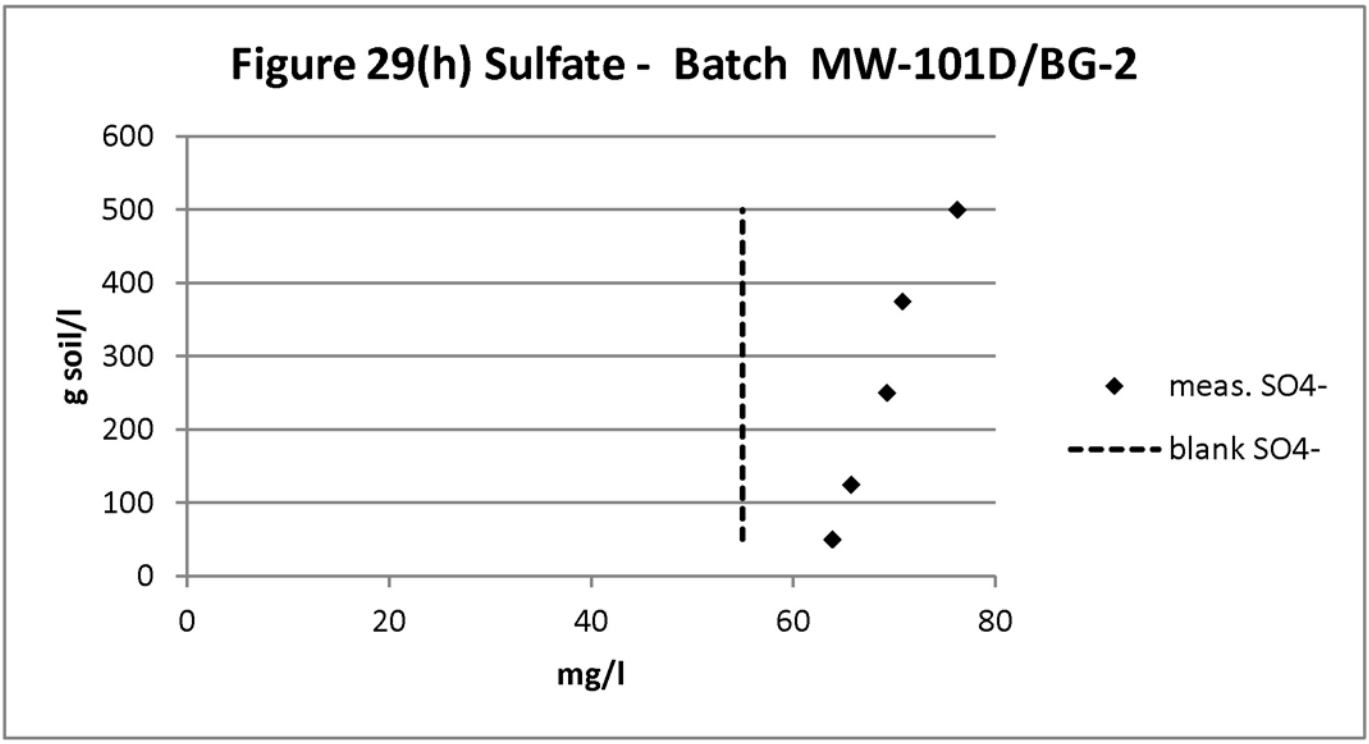


Figure 29(h) Sulfate - Batch MW-101D/BG-2
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

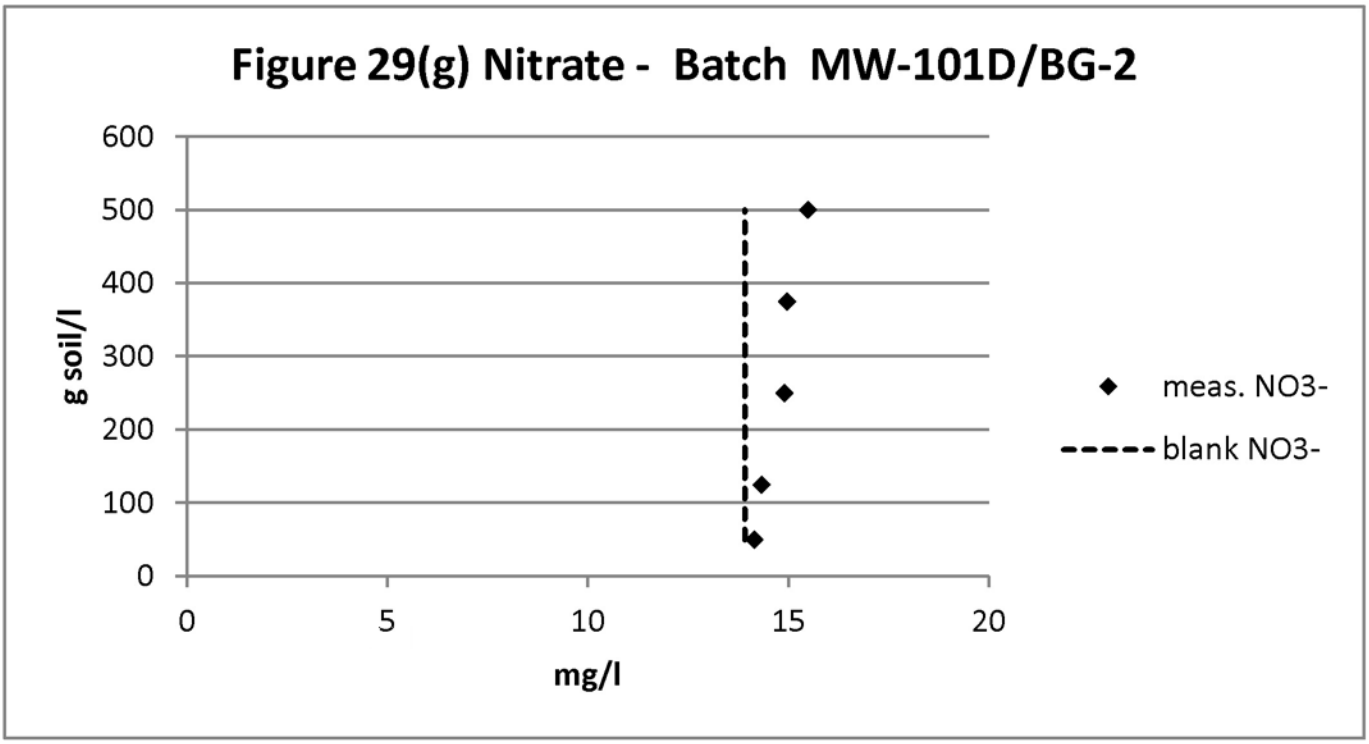


Figure 29(g) Nitrate - Batch MW-101D/BG-2
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

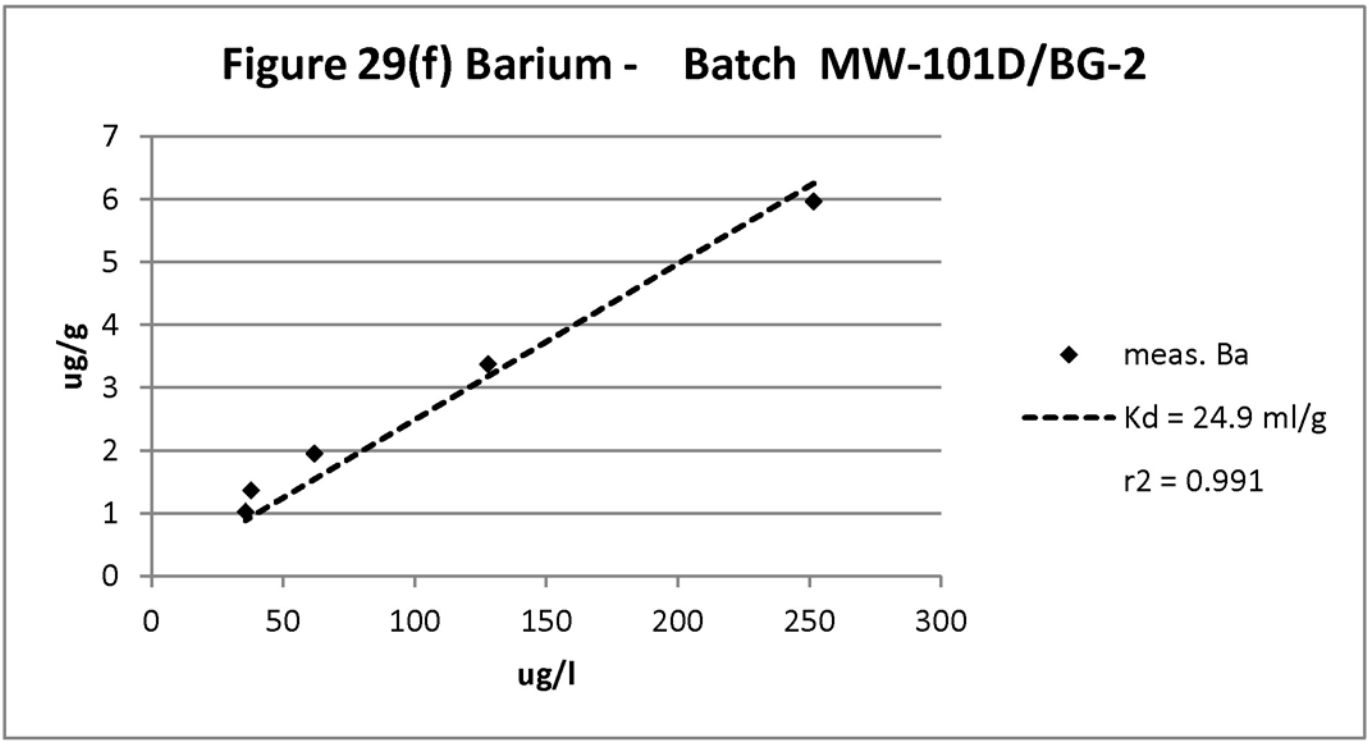


Figure 29(f) Barium - Batch MW-101D/BG-2
ug/g
ug/l
0
1
2
3
4
5
6
7
0
50
100
150
200
250
300
meas. Ba
Kd = 24.9 ml/g
r2 = 0.991

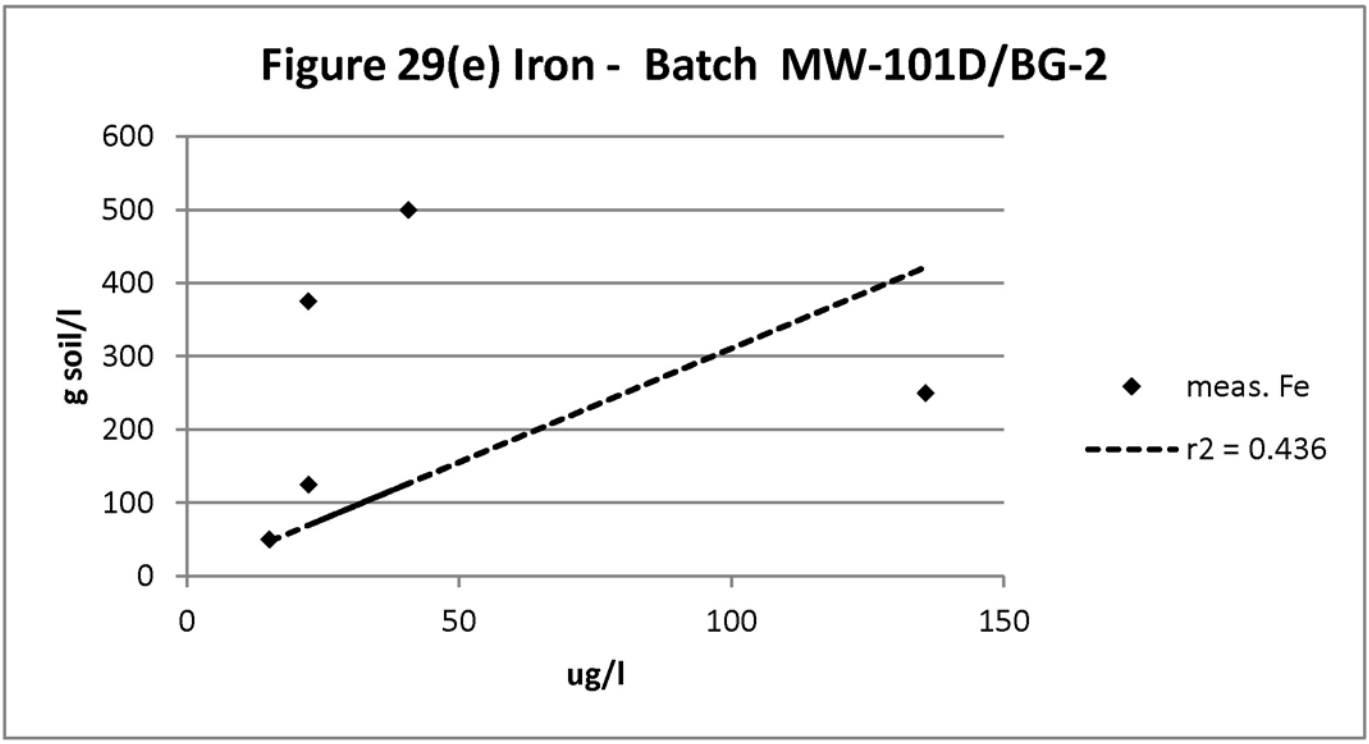


Figure 29(e) Iron - Batch MW-101D/BG-2
600
500
400
300
200
100
0
g soil/l
0
50
100
150
ug/l
meas. Fe
r2 = 0.436

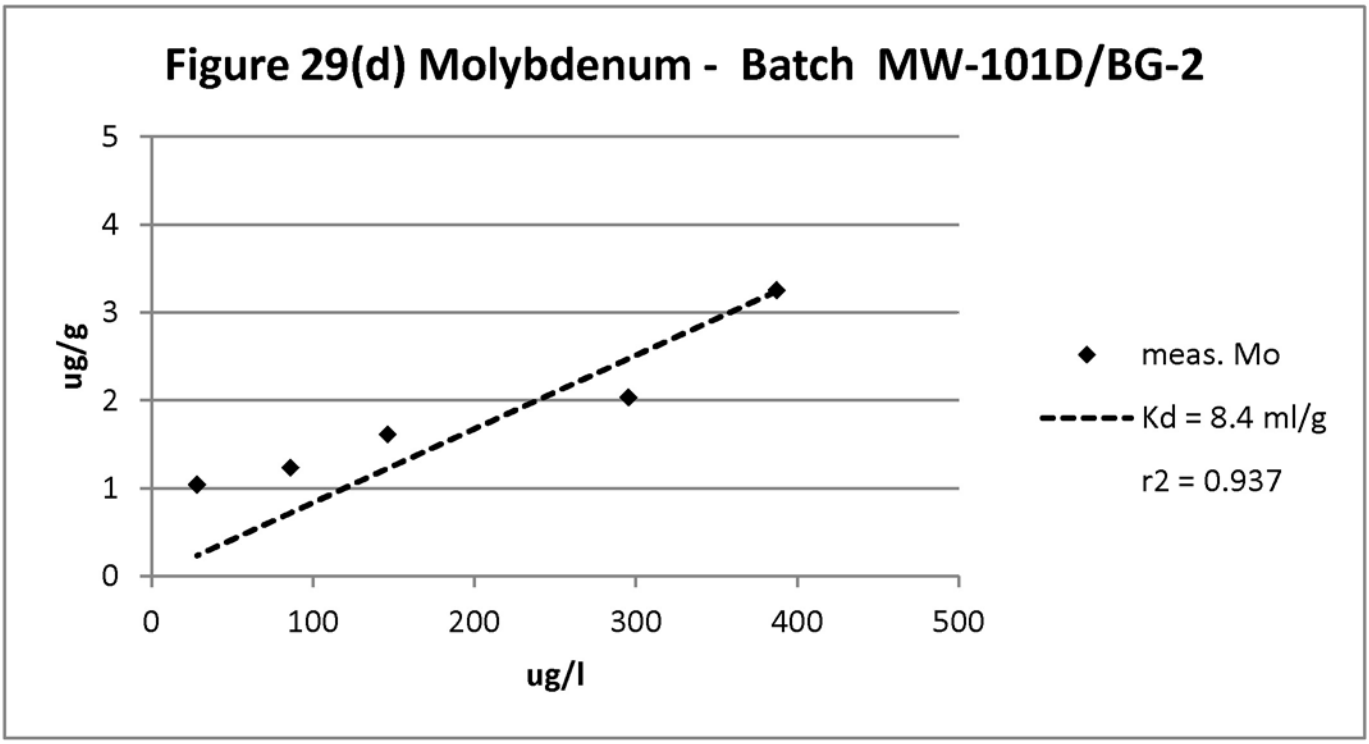


Figure 29(d) Molybdenum - Batch MW-101D/BG-2
5
4
3
2
1
0
ug/g
0
100
200
300
400
500
ug/l
meas. Mo
Kd = 8.4 ml/g
r2 = 0.937

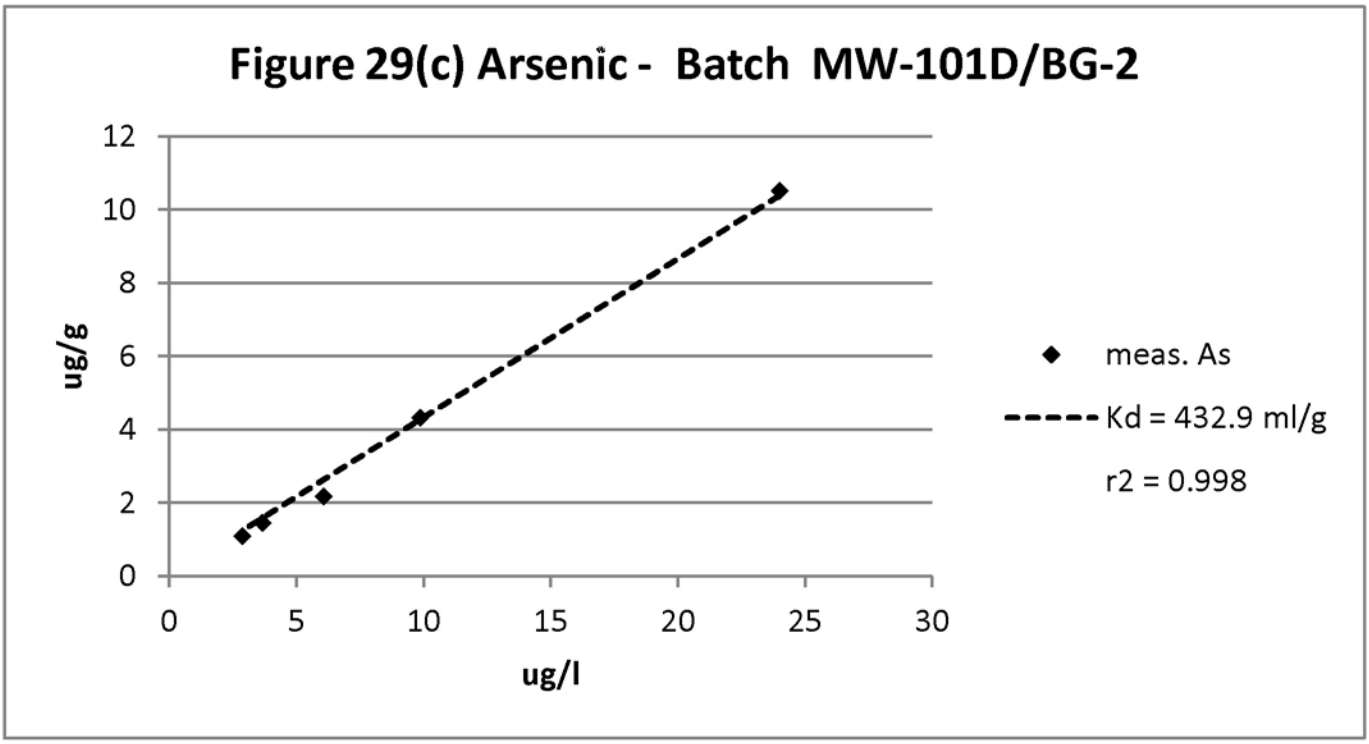


Figure 29(c) Arsenic - Batch MW-101D/BG-2
12
10
8
6
4
2
0
ug/g
0
5
10
15
20
25
30
ug/l
meas. As
Kd = 432.9 ml/g
r2 = 0.998

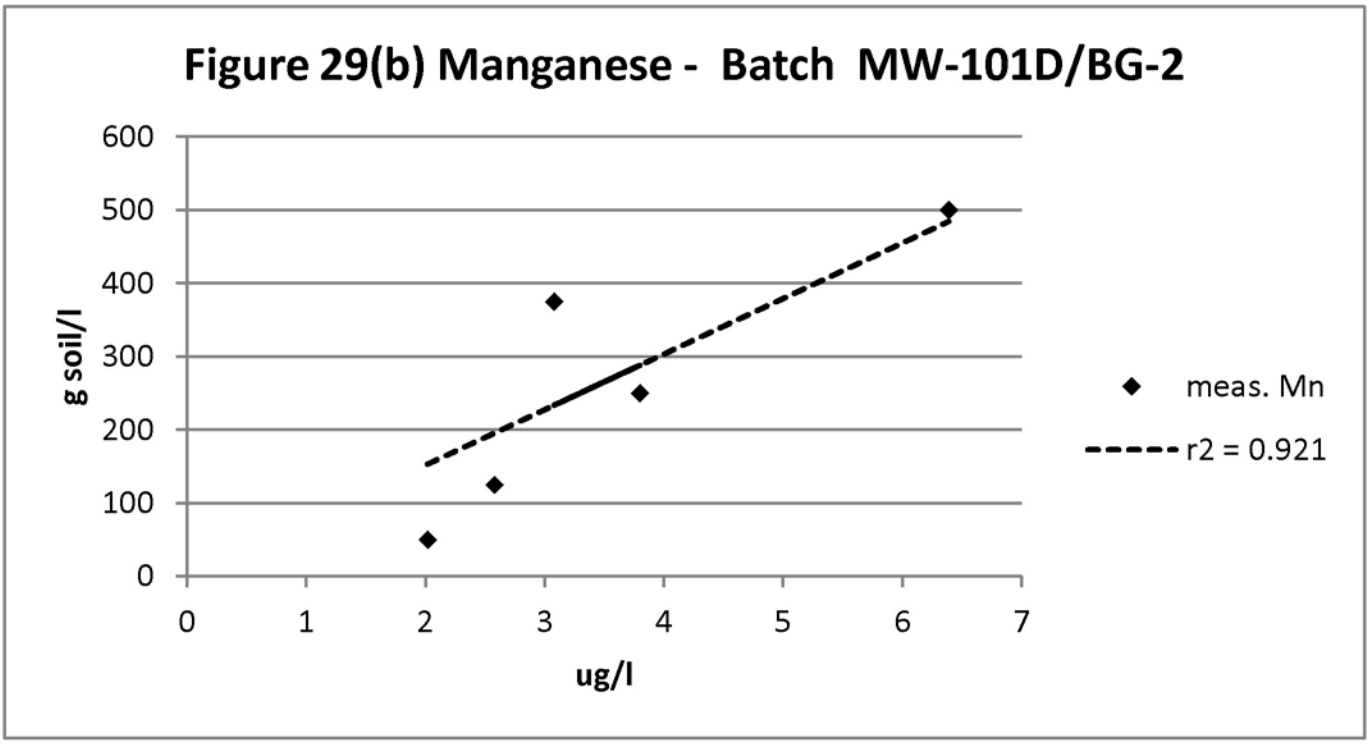


Figure 29(b) Manganese - Batch MW-101D/BG-2
600
500
400
300
200
100
0
g soil/l
0
1
2
3
4
5
6
7
ug/l
meas. Mn
r2 = 0.921

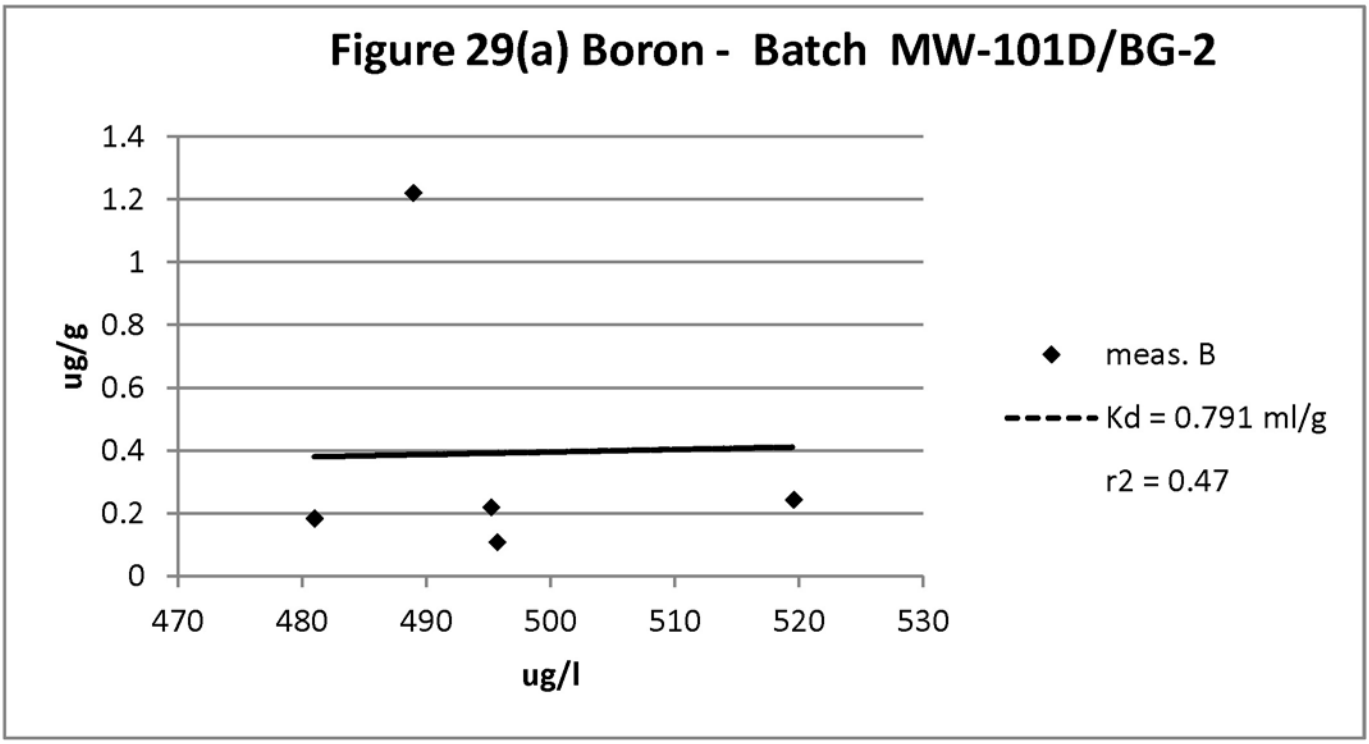


Figure 29(a) Boron - Batch MW-101D/BG-2
1.4
1.2
1
0.8
0.6
0.4
0.2
0
ug/g
470
480
490
500
510
520
530
ug/l
meas. B
Kd = 0.791 ml/g
r2 = 0.47

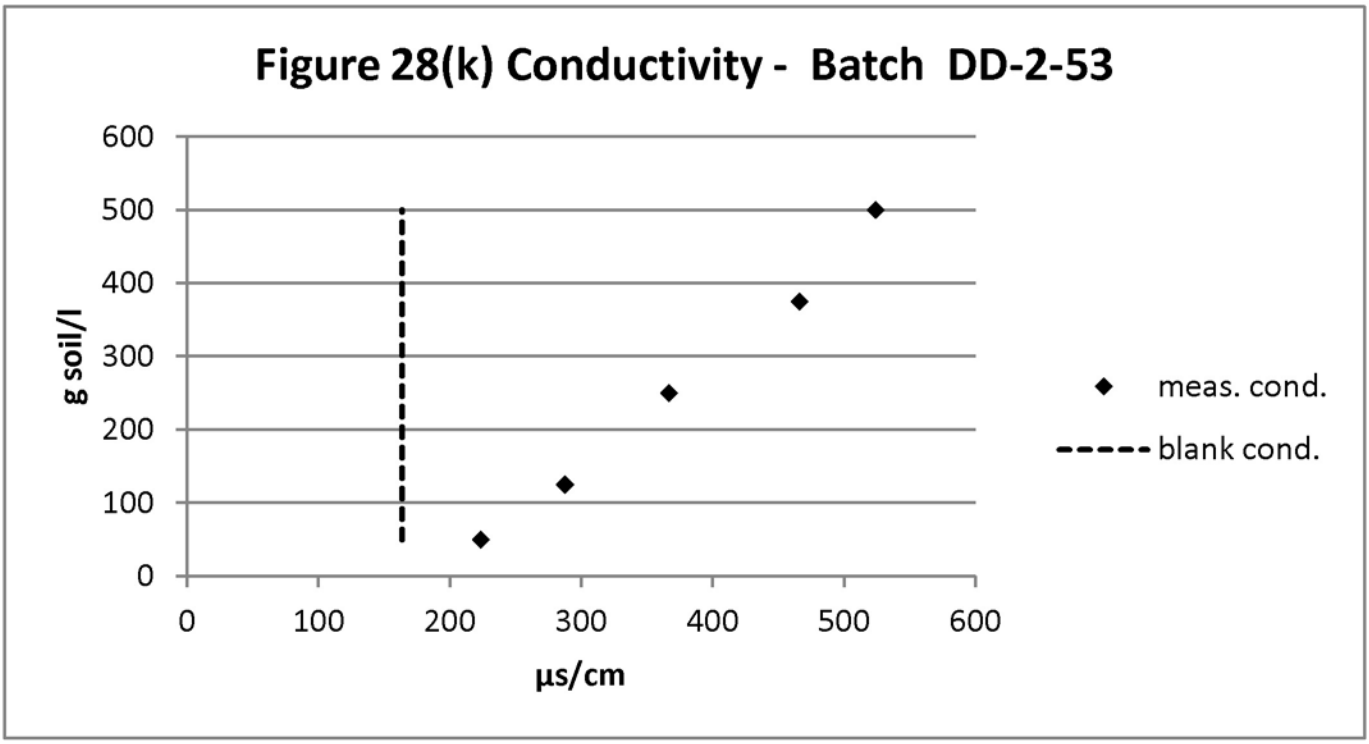


Figure 28(k) Conductivity - Batch DD-2-53
600
500
400
300
200
100
0
g soil/l
0
100
200
300
400
500
600
µs/cm
meas. cond.
blank cond.

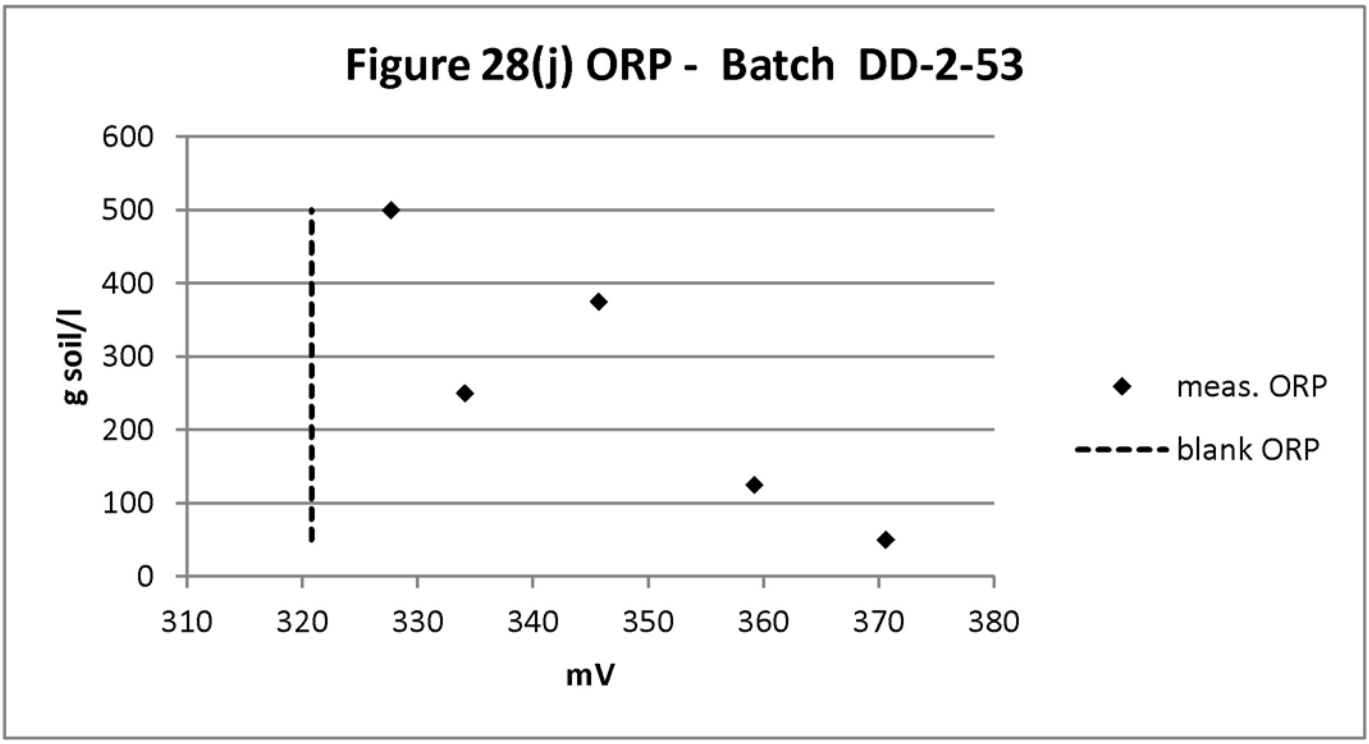


Figure 28(j) ORP - Batch DD-2-53
600
500
400
300
200
100
0
g soil/l
310
320
330
340
350
360
370
380
mV
meas. ORP
blank ORP

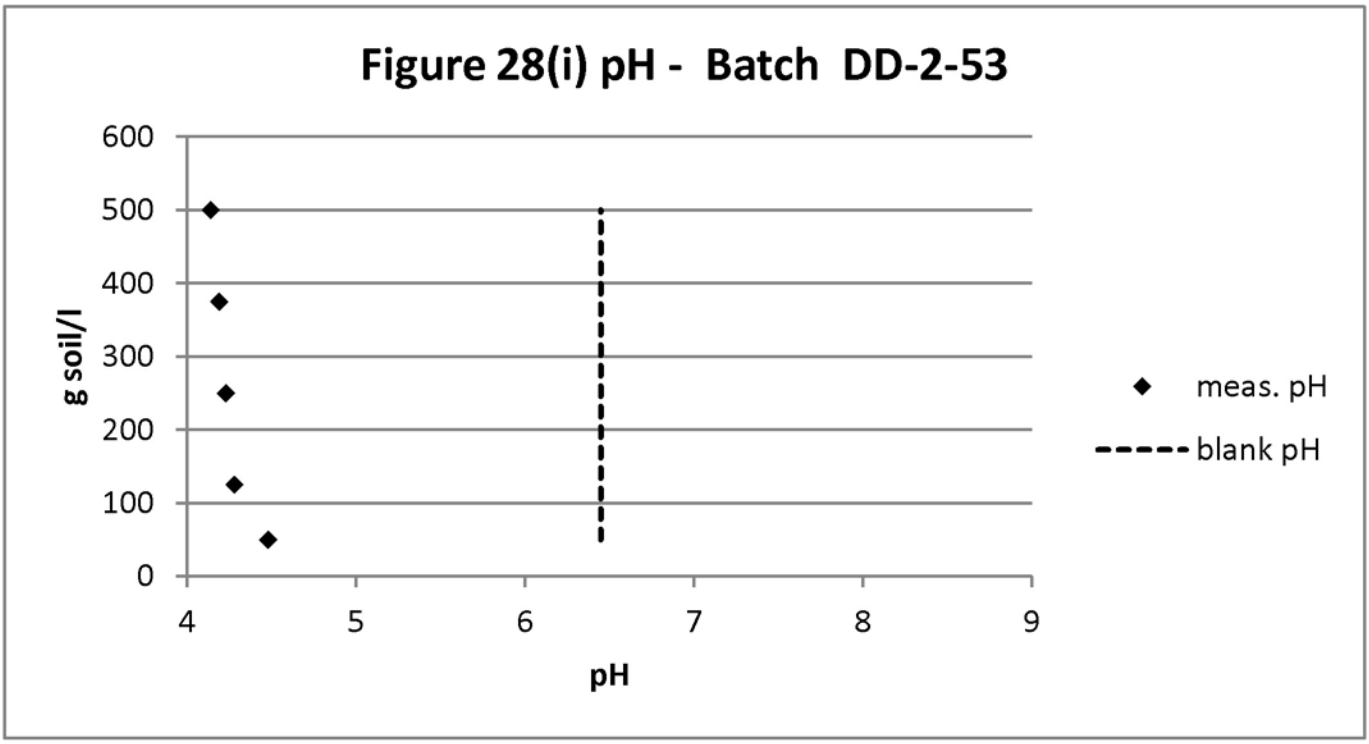


Figure 28(i) pH - Batch DD-2-53
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

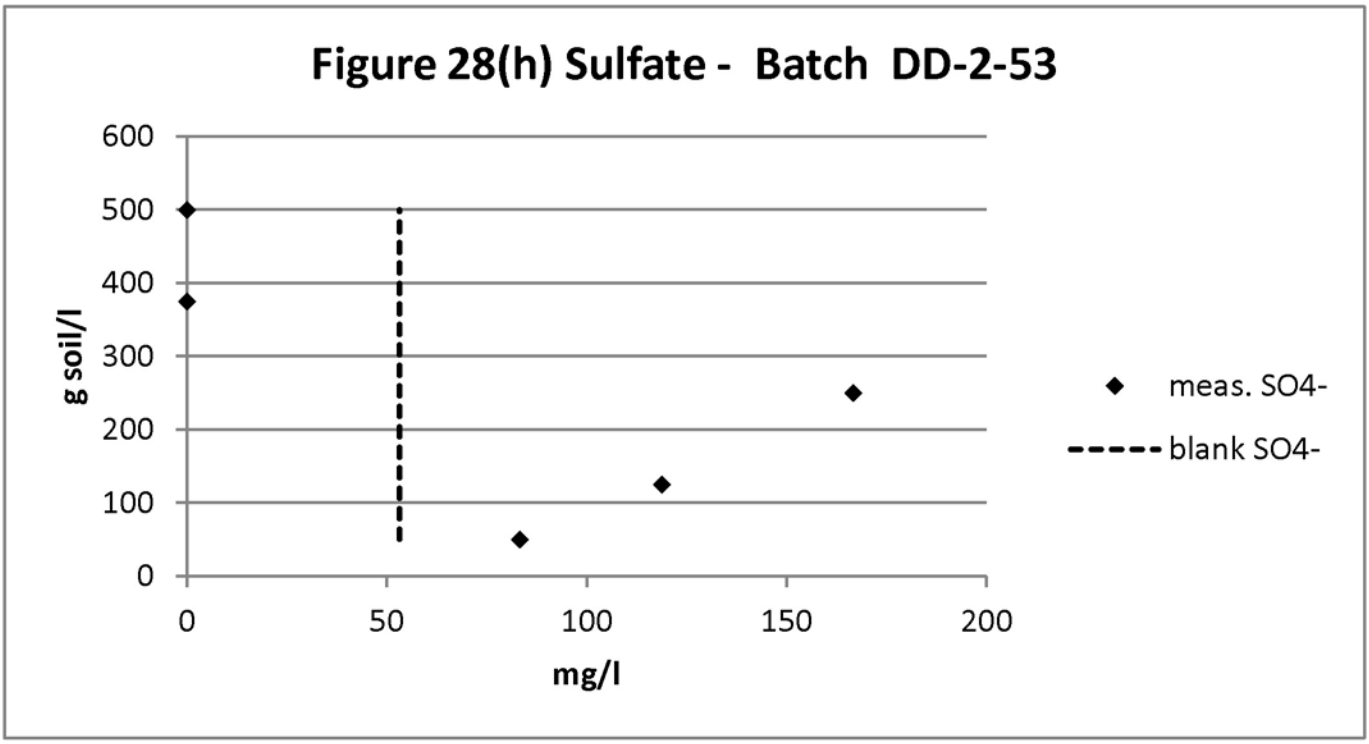


Figure 28(h) Sulfate - Batch DD-2-53
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
mg/l
meas. SO4-
blank SO4-

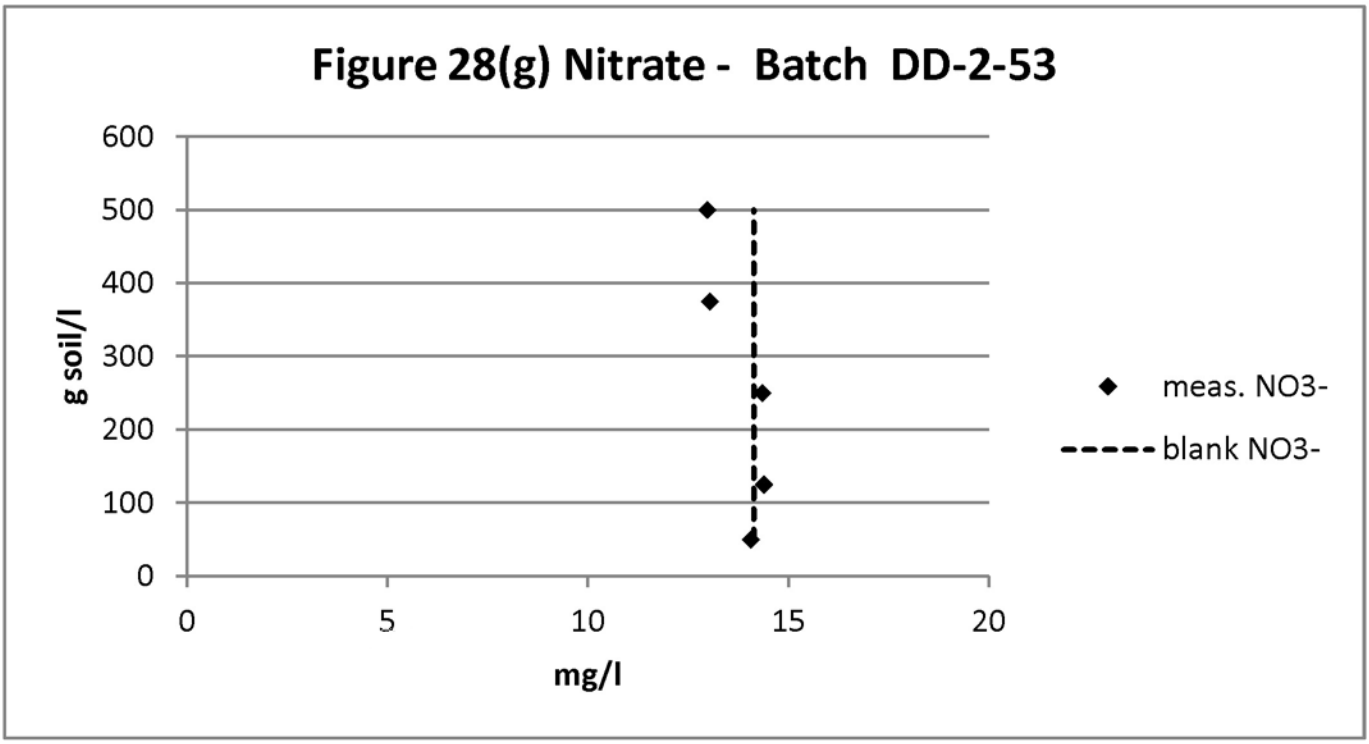


Figure 28(g) Nitrate - Batch DD-2-53
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

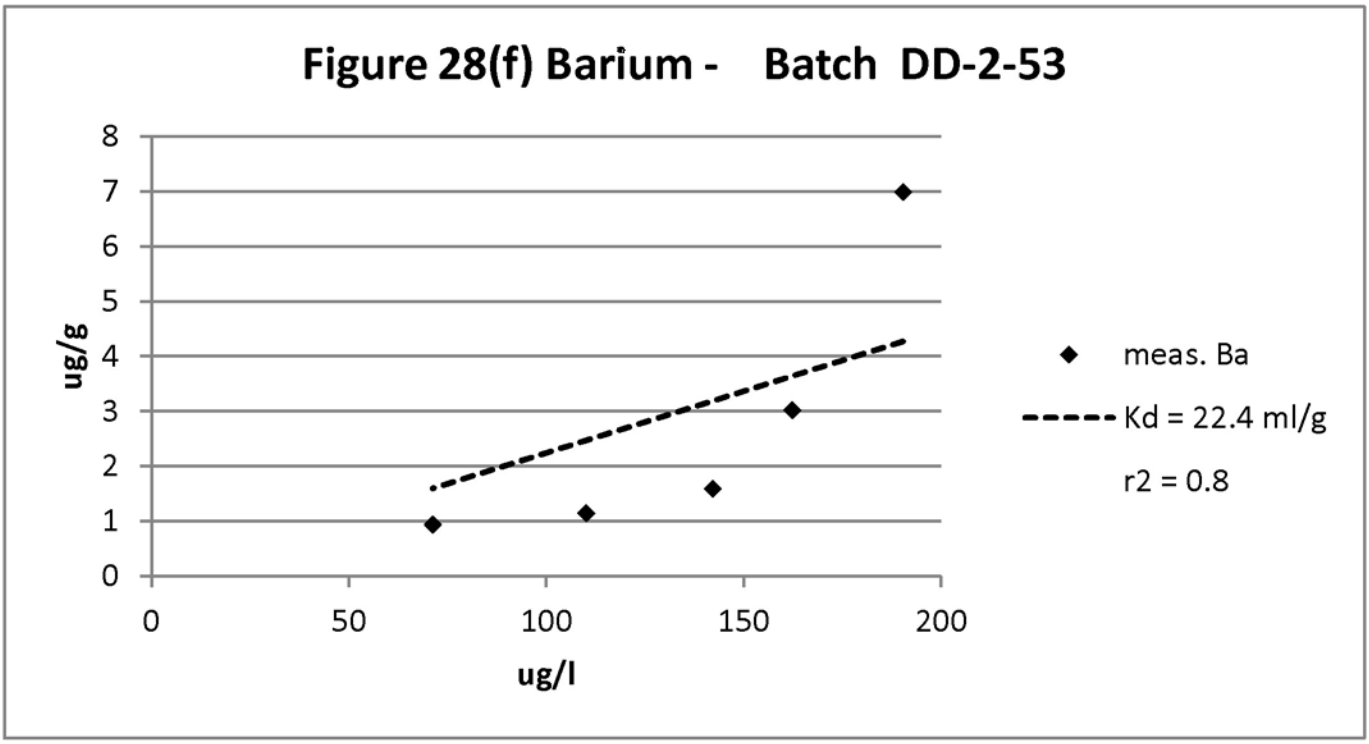


Figure 28(f) Barium - Batch DD-2-53
8
7
6
5
4
3
2
1
0
ug/g
0
50
100
150
200
ug/l
meas. Ba
Kd = 22.4 ml/g
r2 = 0.8

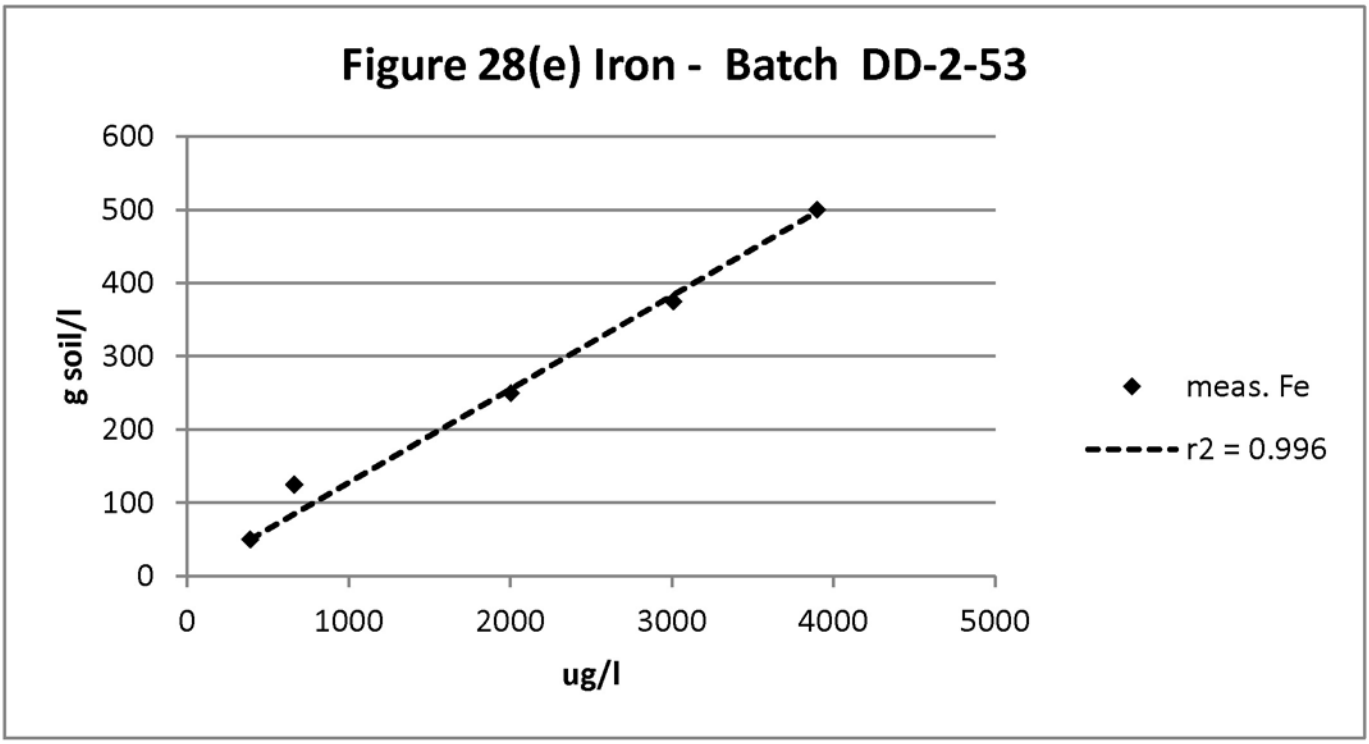


Figure 28(e) Iron - Batch DD-2-53
600
500
400
300
200
100
0
g soil/l
0
1000
2000
3000
4000
5000
ug/l
meas. Fe
r2 = 0.996

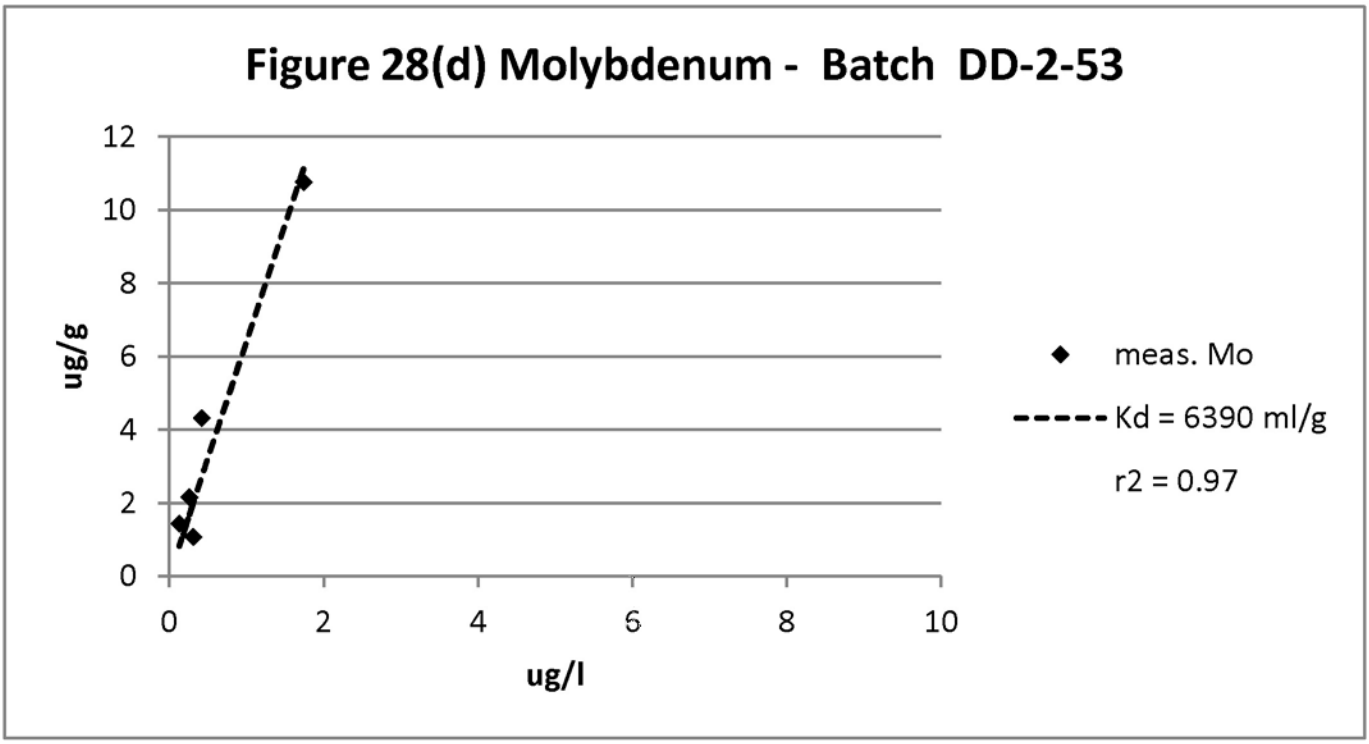


Figure 28(d) Molybdenum - Batch DD-2-53
12
10
8
6
4
2
0
ug/g
0
2
4
6
8
10
ug/l
meas. Mo
Kd = 6390 ml/g
r2 = 0.97

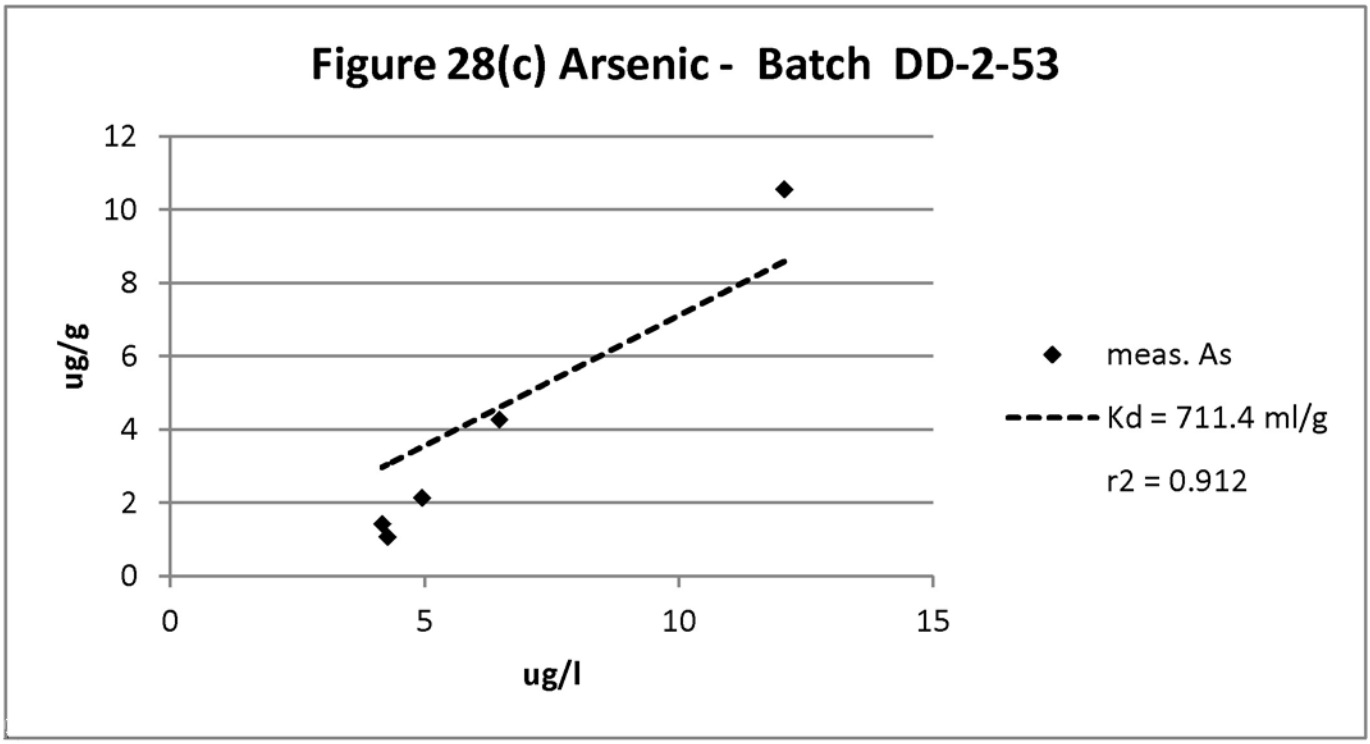


Figure 28(c) Arsenic - Batch DD-2-53
12
10
8
6
4
2
0
ug/g
0
5
10
15
ug/l
meas. As
Kd = 711.4 ml/g
r2 = 0.912

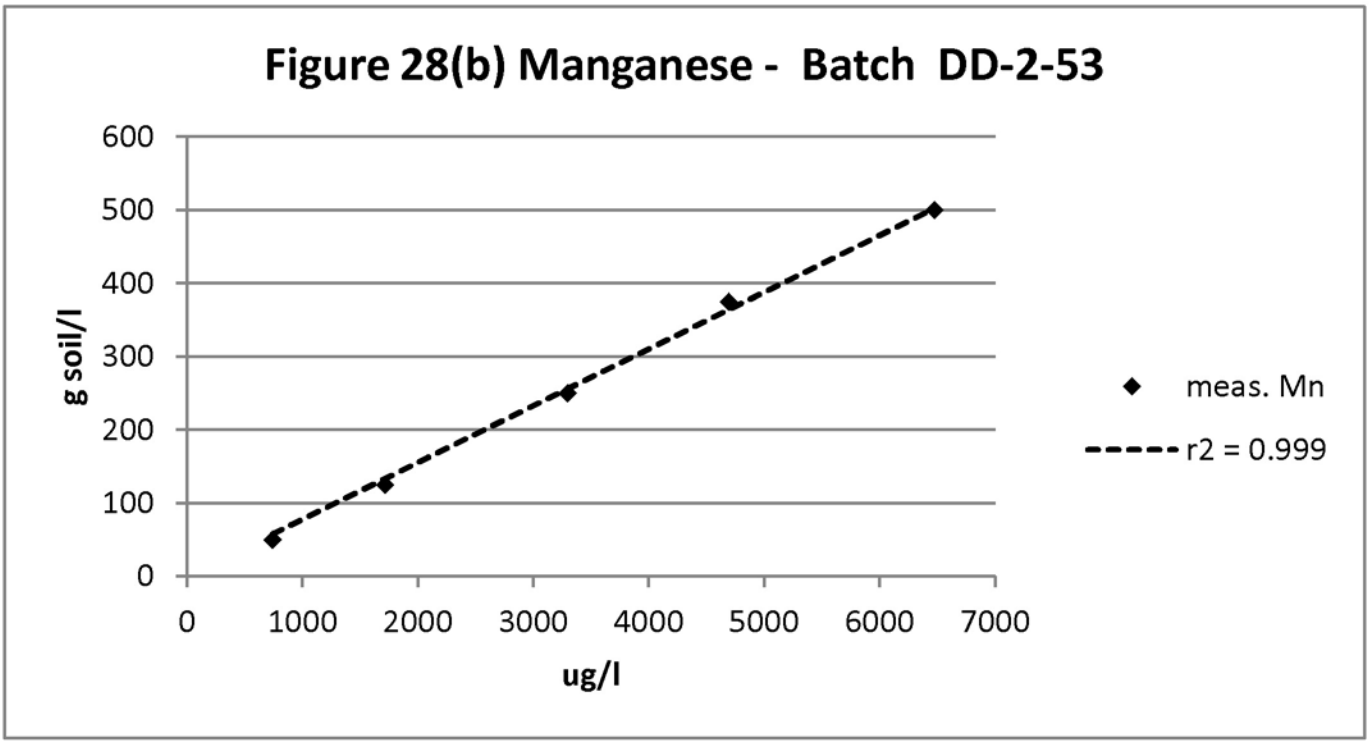


Figure 28(b) Manganese - Batch DD-2-53
600
500
400
300
200
100
0
g soil/l
0
1000
2000
3000
4000
5000
6000
7000
ug/l
meas. Mn
r2 = 0.999

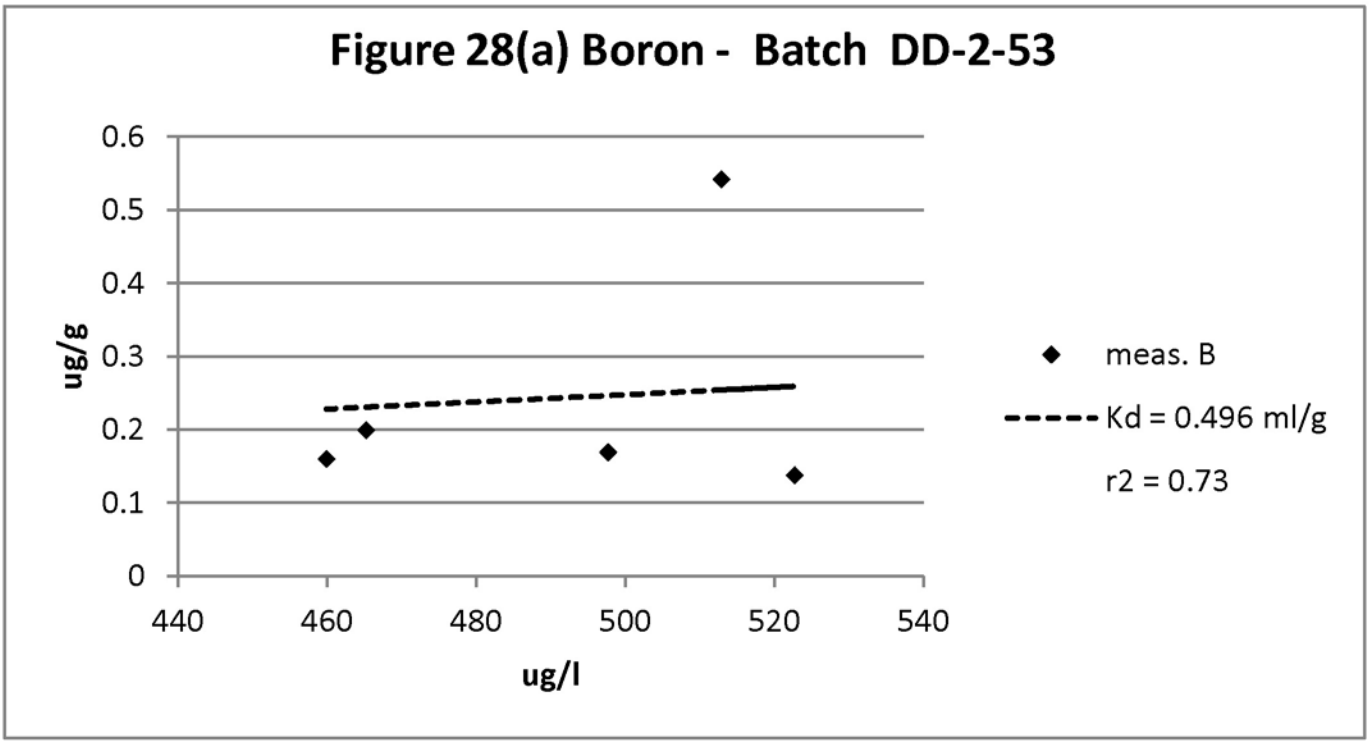


Figure 28(a) Boron - Batch DD-2-53
0.6
0.5
0.4
0.3
0.2
0.1
0
ug/g
440
460
480
500
520
540
ug/l
meas. B
Kd = 0.496 ml/g
r2 = 0.73

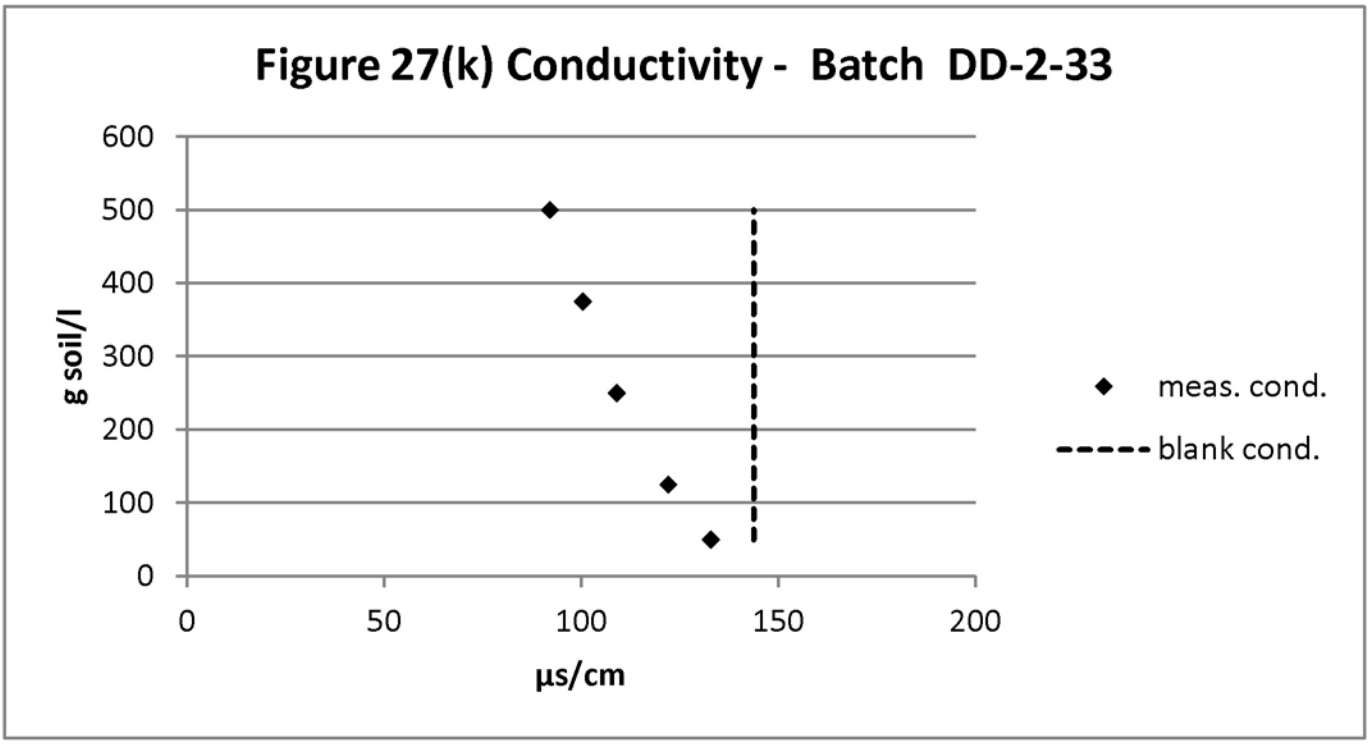


Figure 27(k) Conductivity - Batch DD-2-33
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
µs/cm
meas. cond.
blank cond.

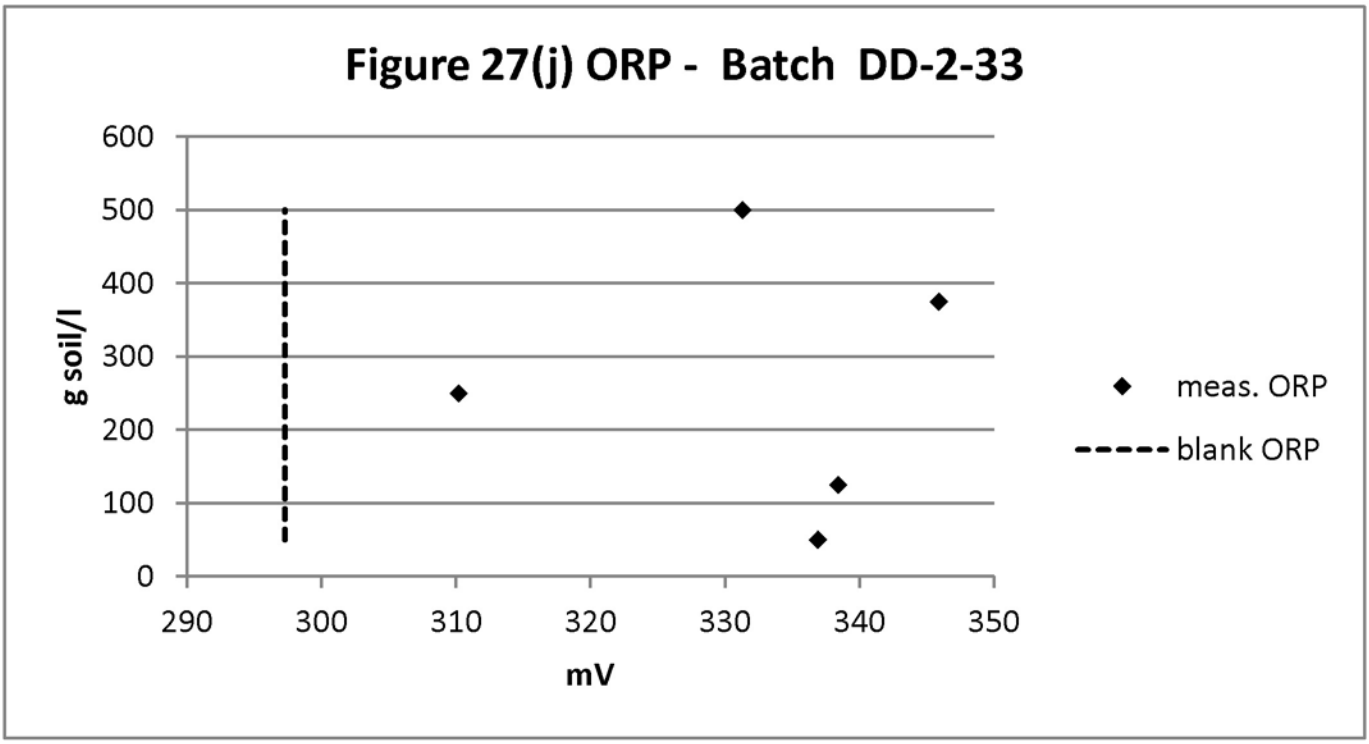


Figure 27(j) ORP - Batch DD-2-33
600
500
400
300
200
100
0
g soil/l
290
300
310
320
330
340
350
mV
meas. ORP
blank ORP

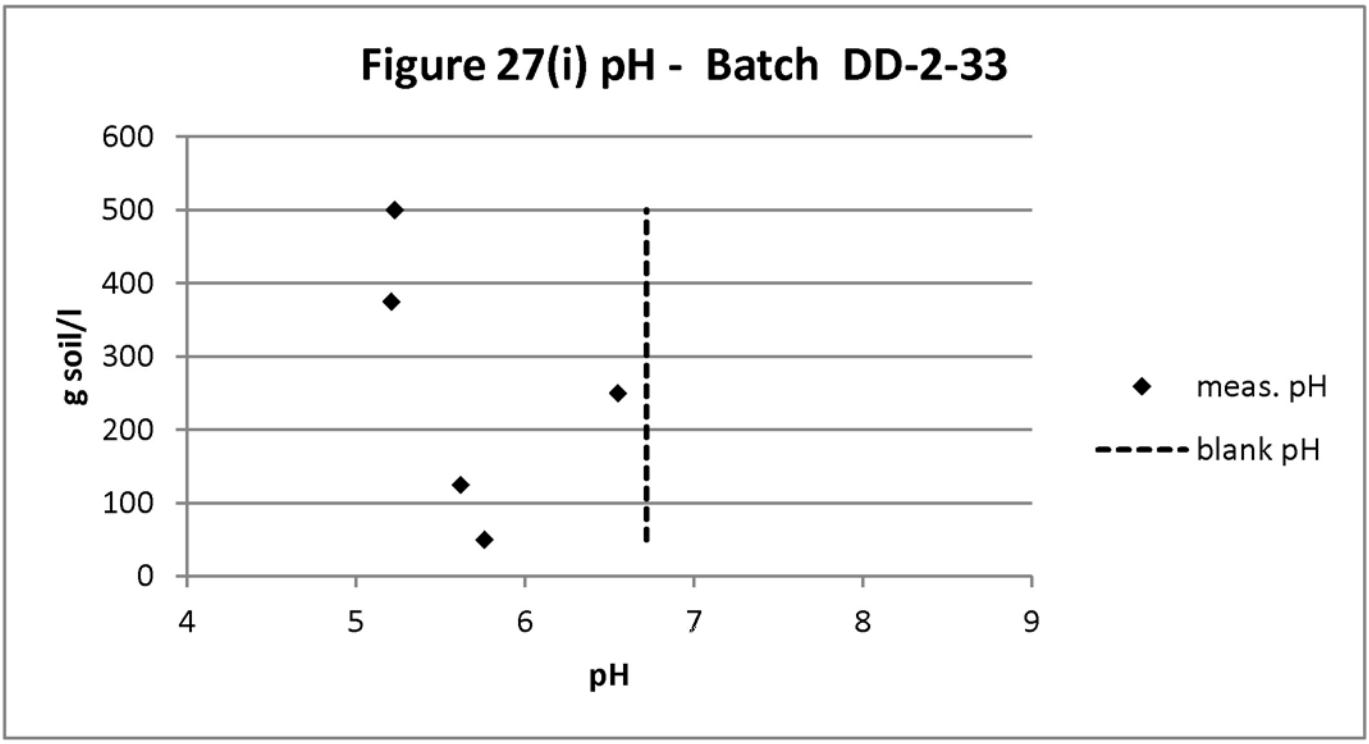


Figure 27(i) pH - Batch DD-2-33
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

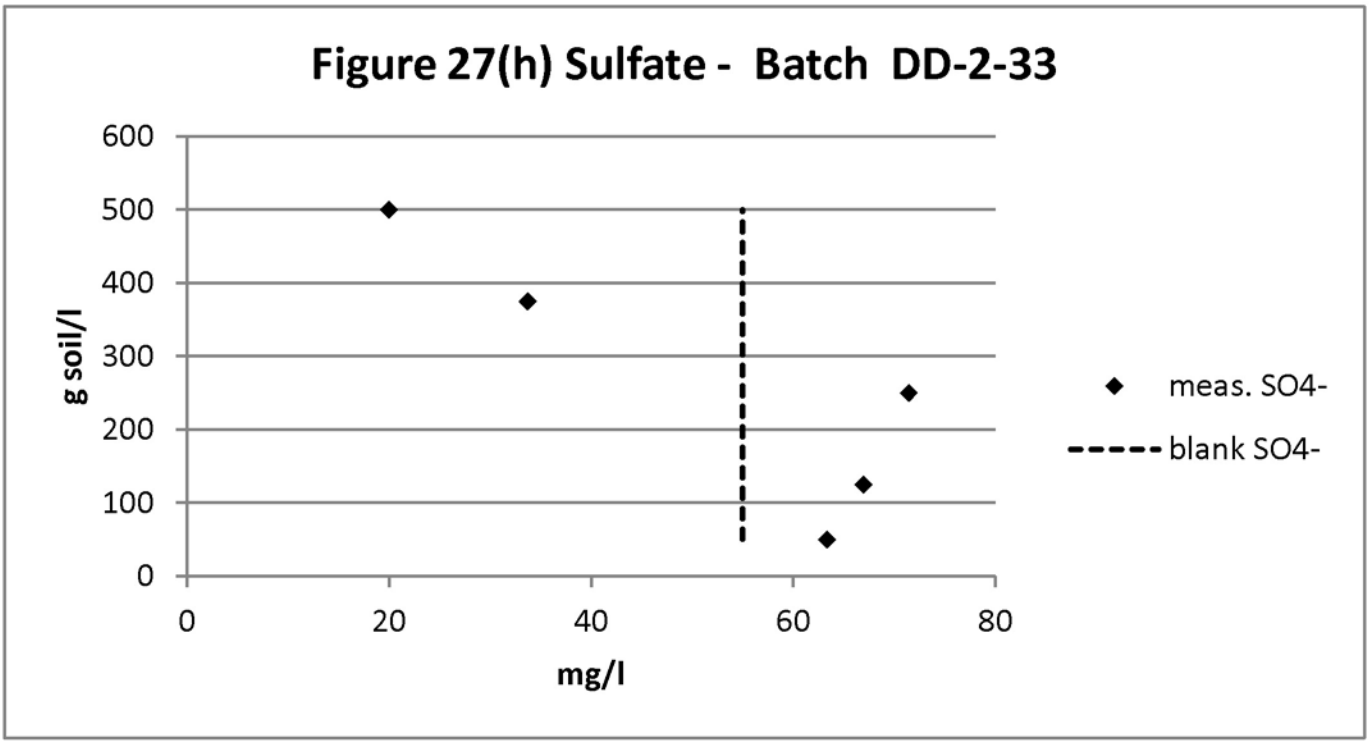


Figure 27(h) Sulfate - Batch DD-2-33
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

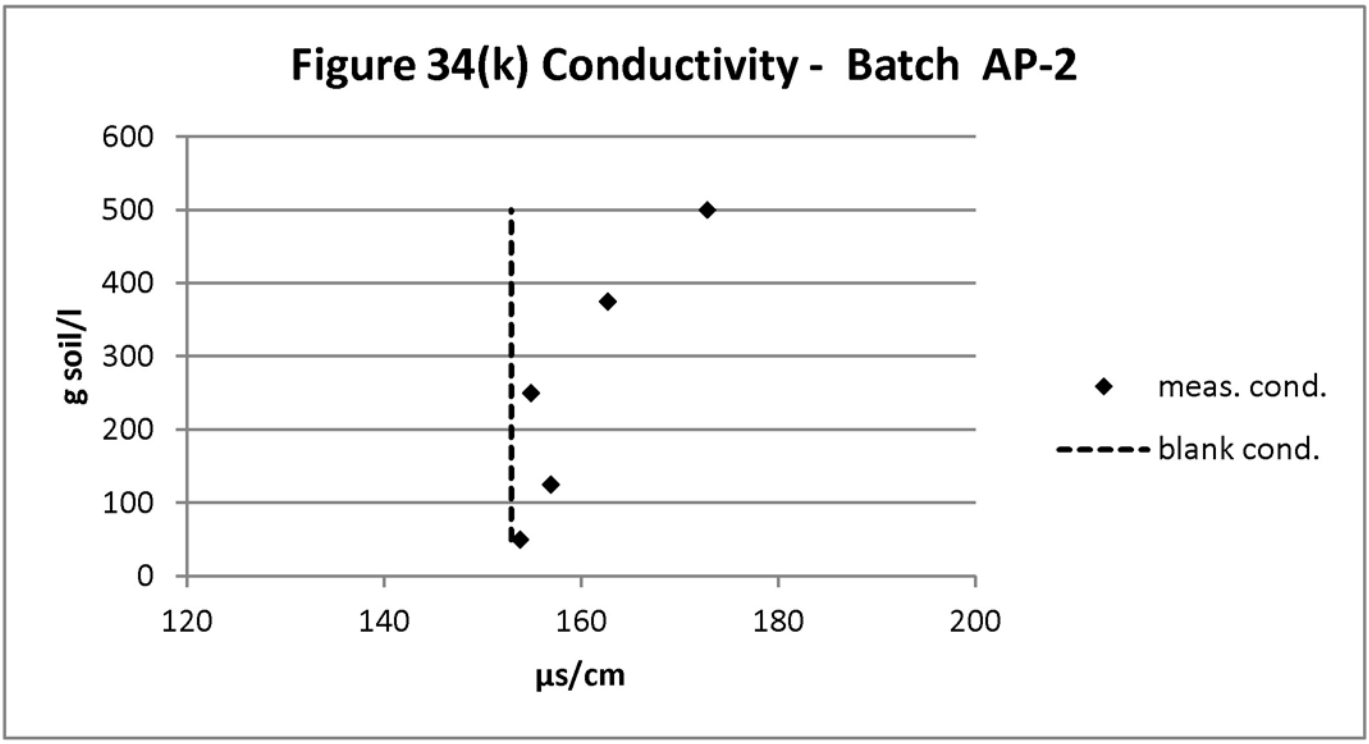


Figure 34(k) Conductivity - Batch AP-2
600
500
400
300
200
100
0
g soil/l
120
140
160
180
200
µs/cm
meas. cond.
blank cond.

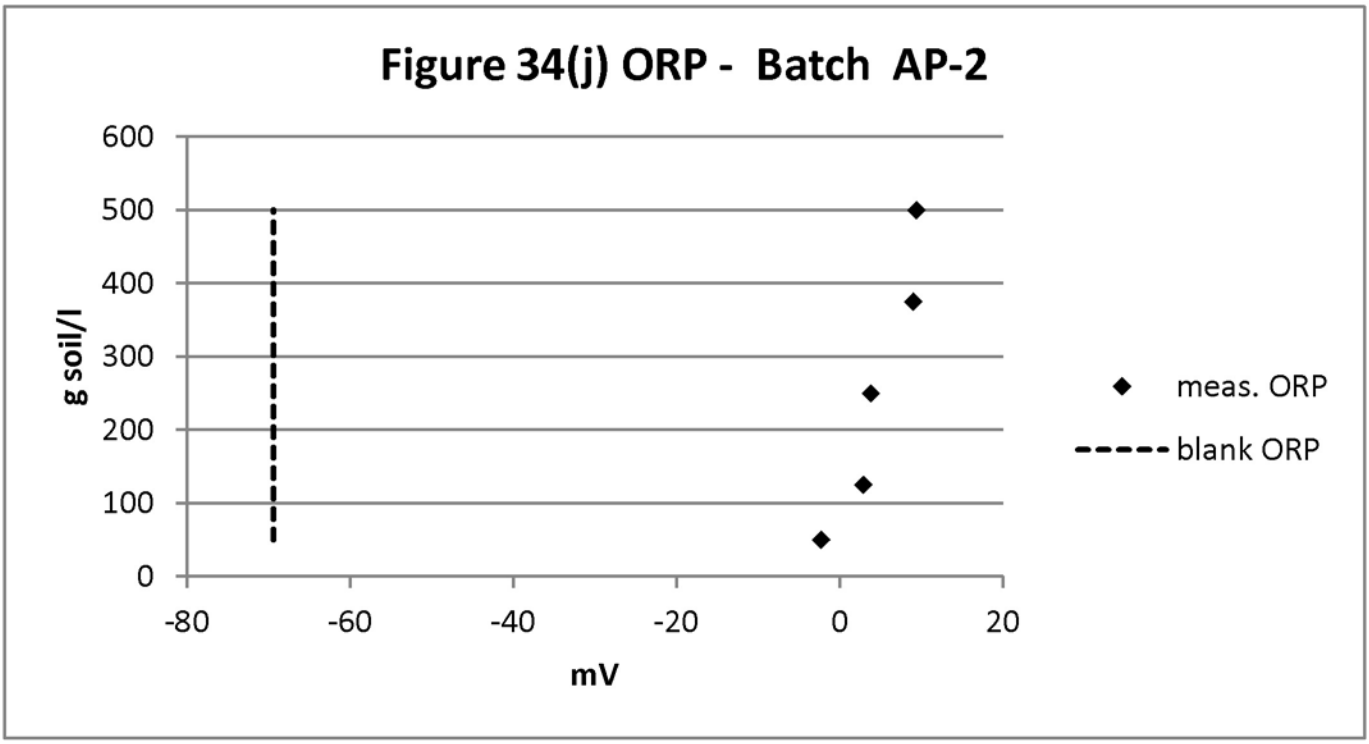


Figure 34(j) ORP - Batch AP-2
600
500
400
300
200
100
0
g soil/l
-80
-60
-40
-20
0
20
mV
meas. ORP
blank ORP

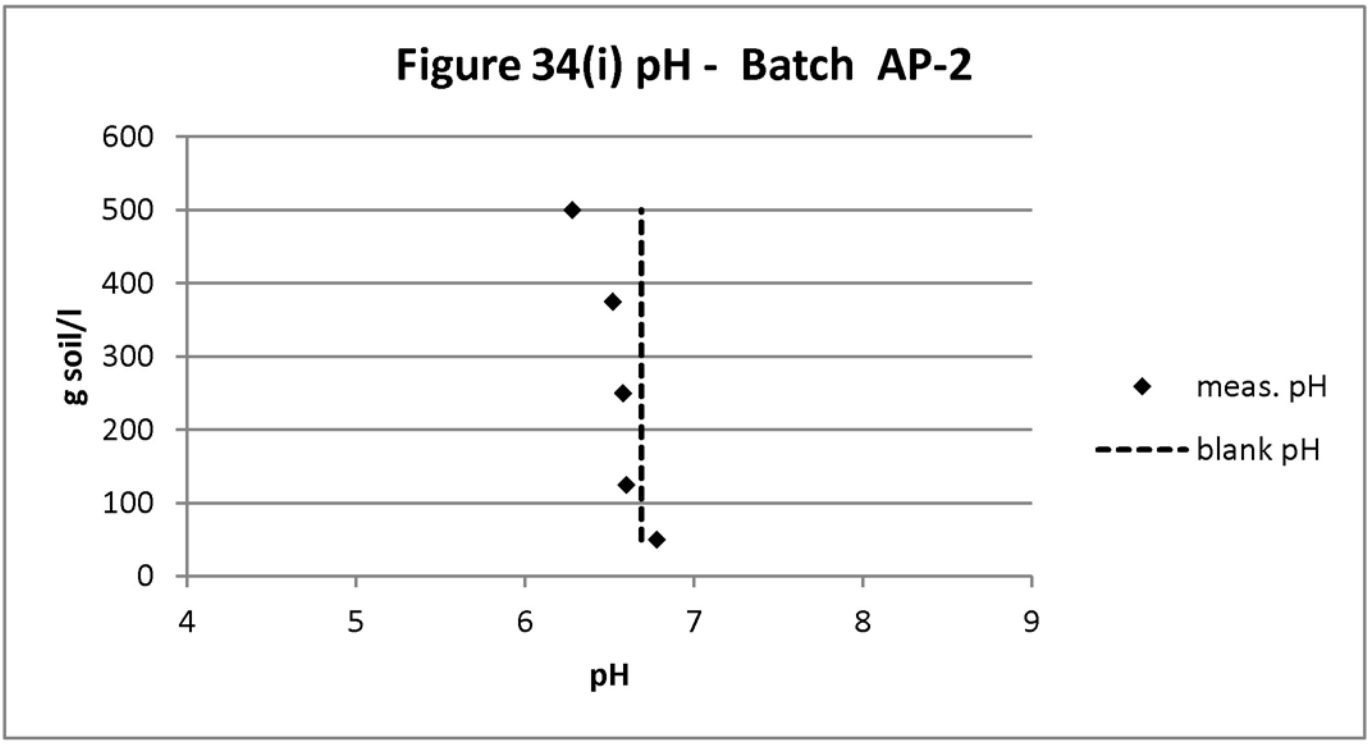


Figure 34(i) pH - Batch AP-2
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

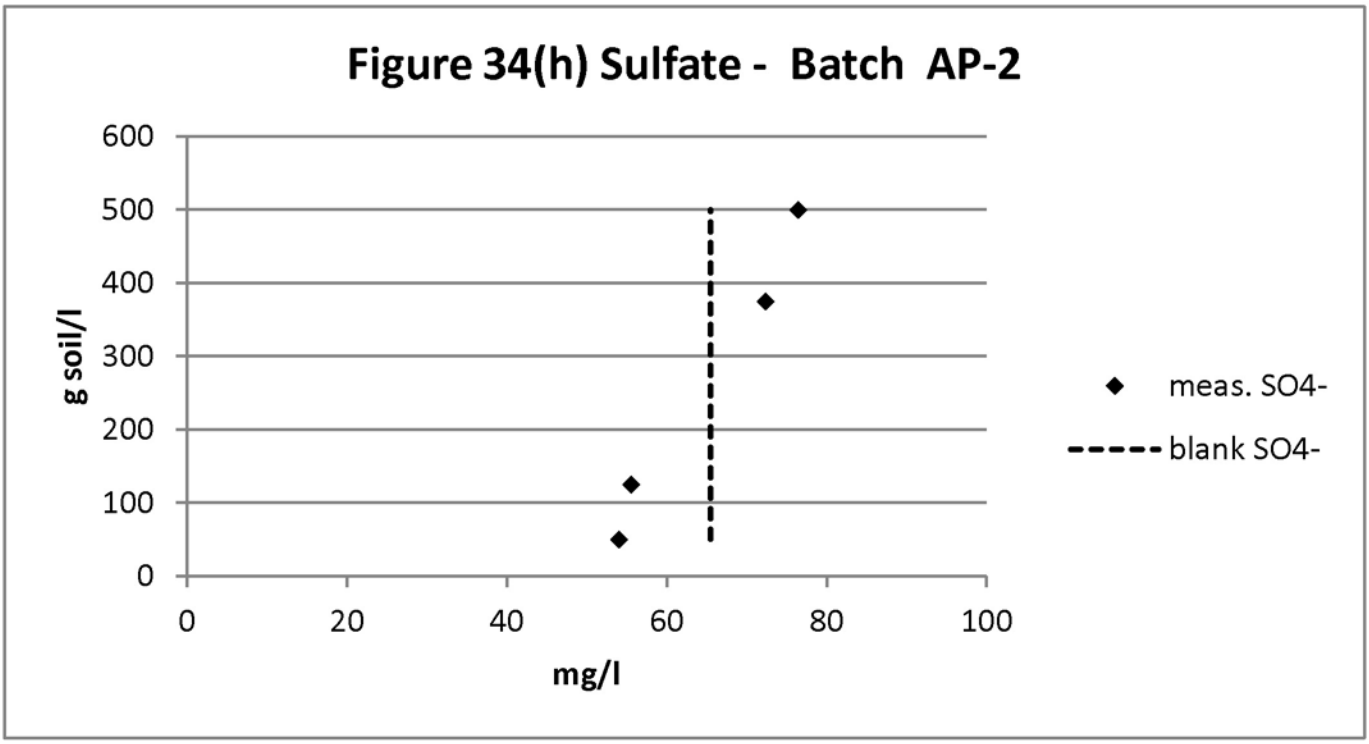


Figure 34(h) Sulfate - Batch AP-2
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
100
mg/l
meas. SO4-
blank SO4-

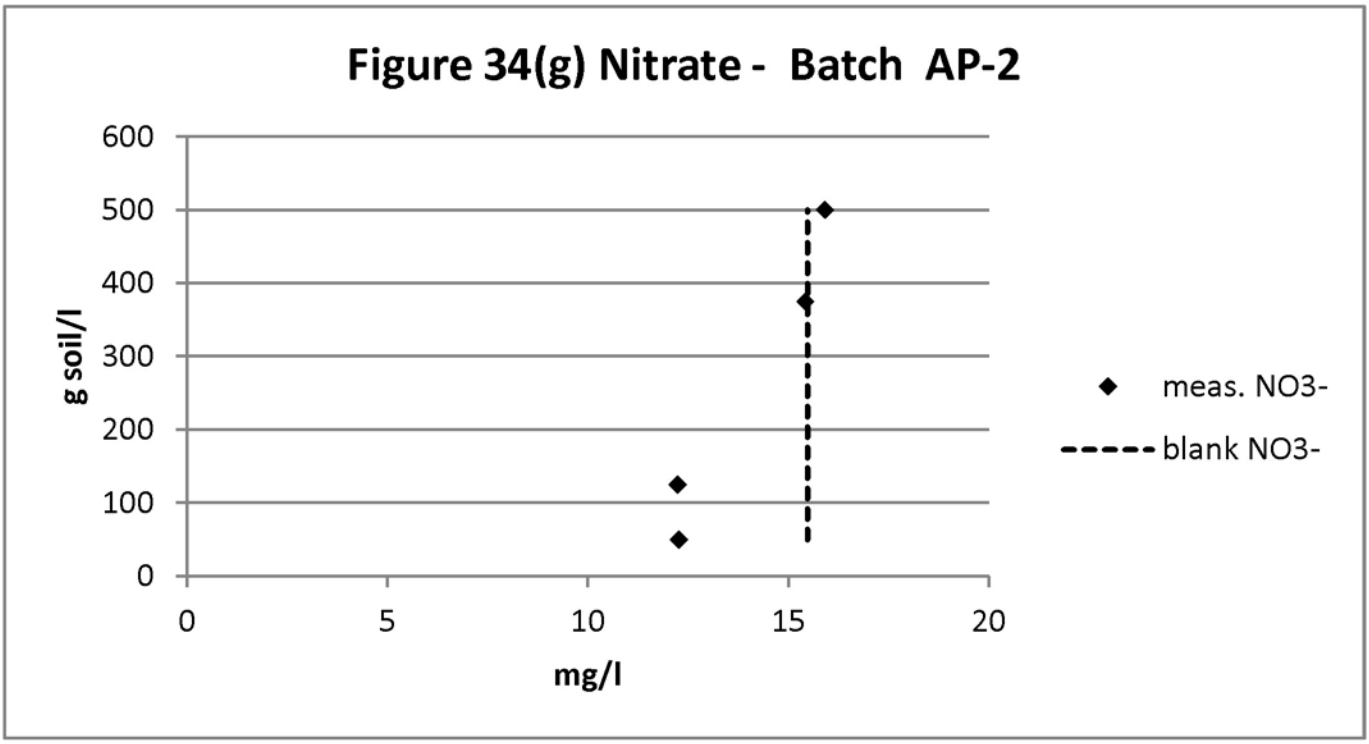


Figure 34(g) Nitrate - Batch AP-2
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

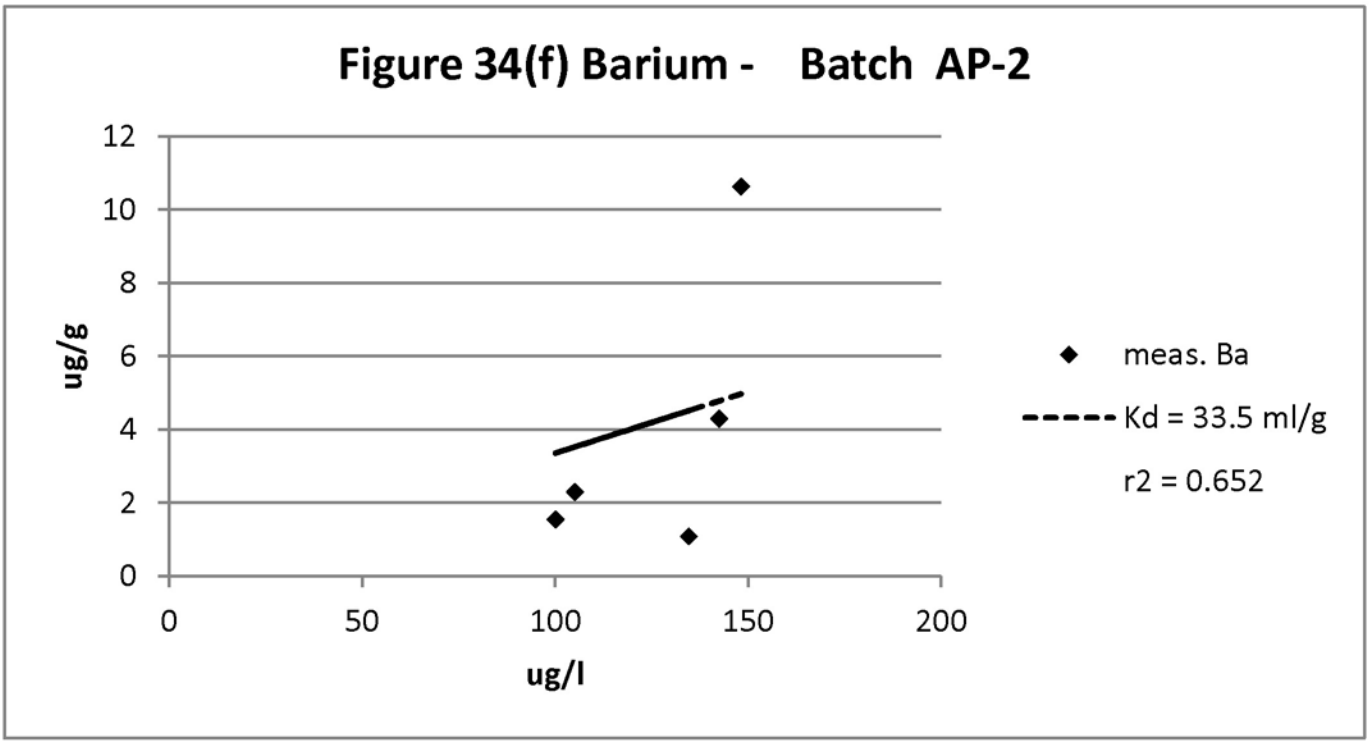


Figure 34(f) Barium - Batch AP-2
12
10
8
6
4
2
0
ug/g
0
50
100
150
200
ug/l
meas. Ba
Kd = 33.5 ml/g
r2 = 0.652

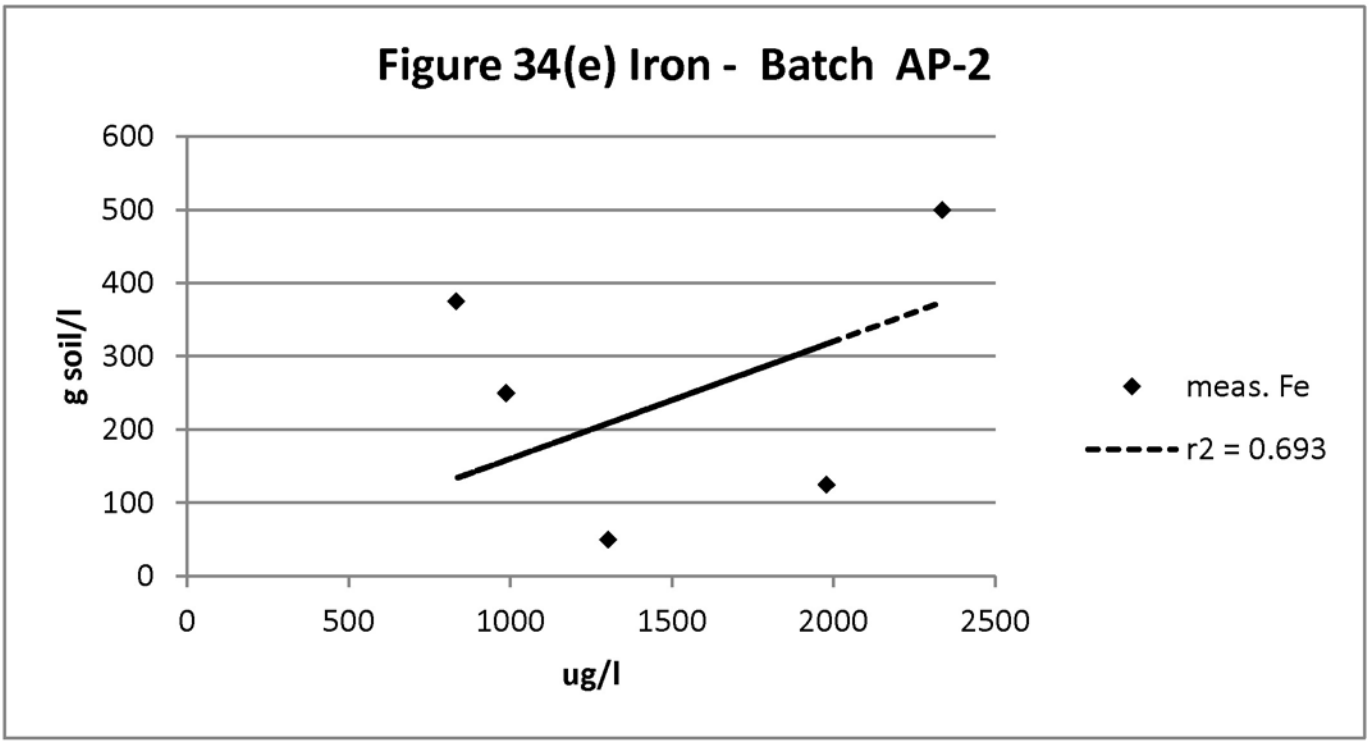


Figure 34(e) Iron - Batch AP-2
600
500
400
300
200
100
0
g soil/l
0
500
1000
1500
2000
2500
ug/l
meas. Fe
r2 = 0.693

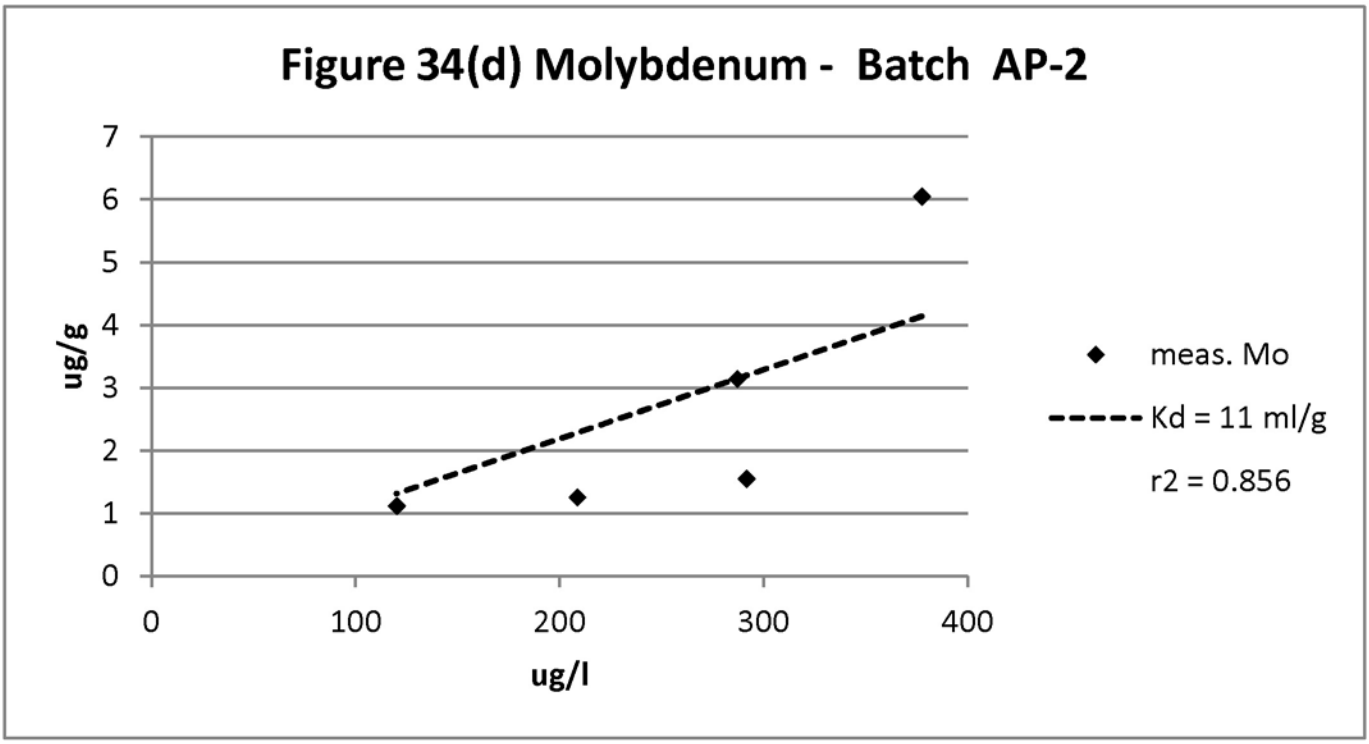


Figure 34(d) Molybdenum - Batch AP-2
7
6
5
4
3
2
1
0
ug/g
0
100
200
300
400
ug/l
meas. Mo
Kd = 11 ml/g
r2 = 0.856

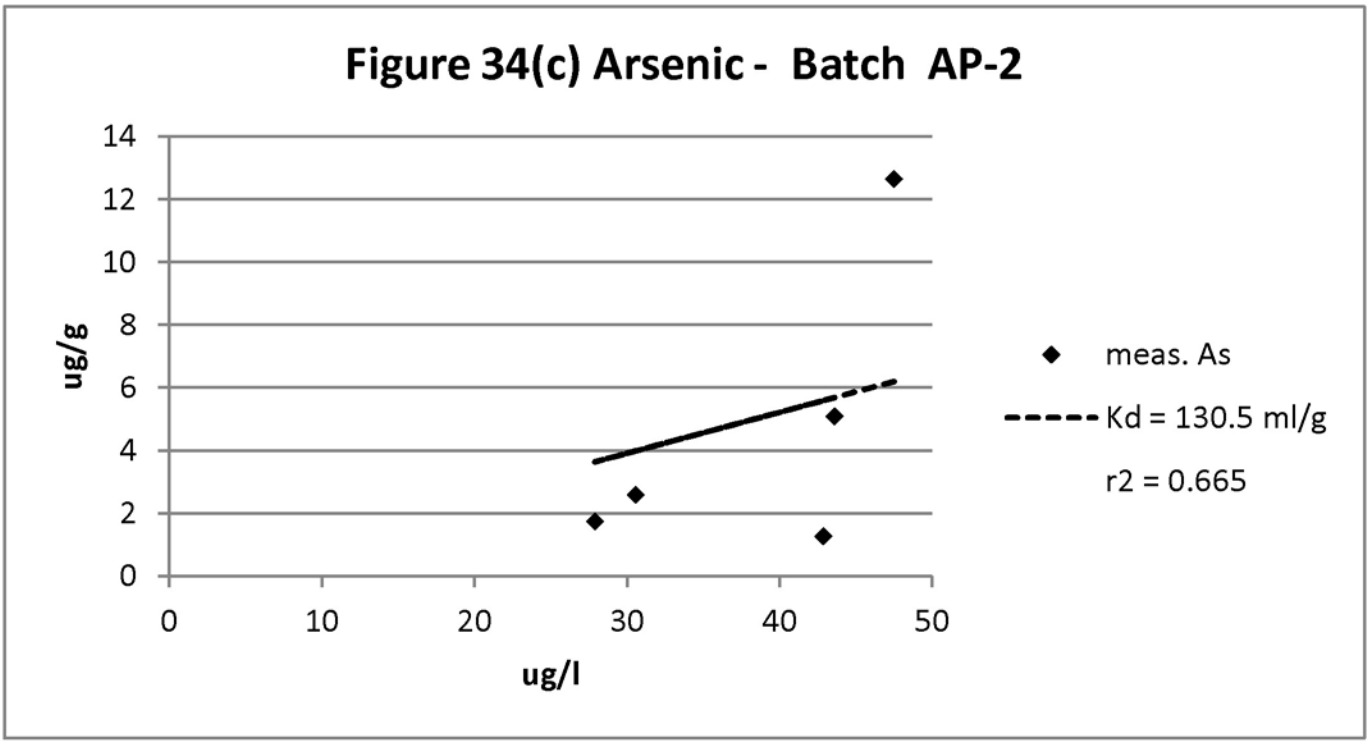


Figure 34(c) Arsenic - Batch AP-2
14
12
10
8
6
4
2
0
ug/g
0
10
20
30
40
50
ug/l
meas. As
Kd = 130.5 ml/g
r2 = 0.665

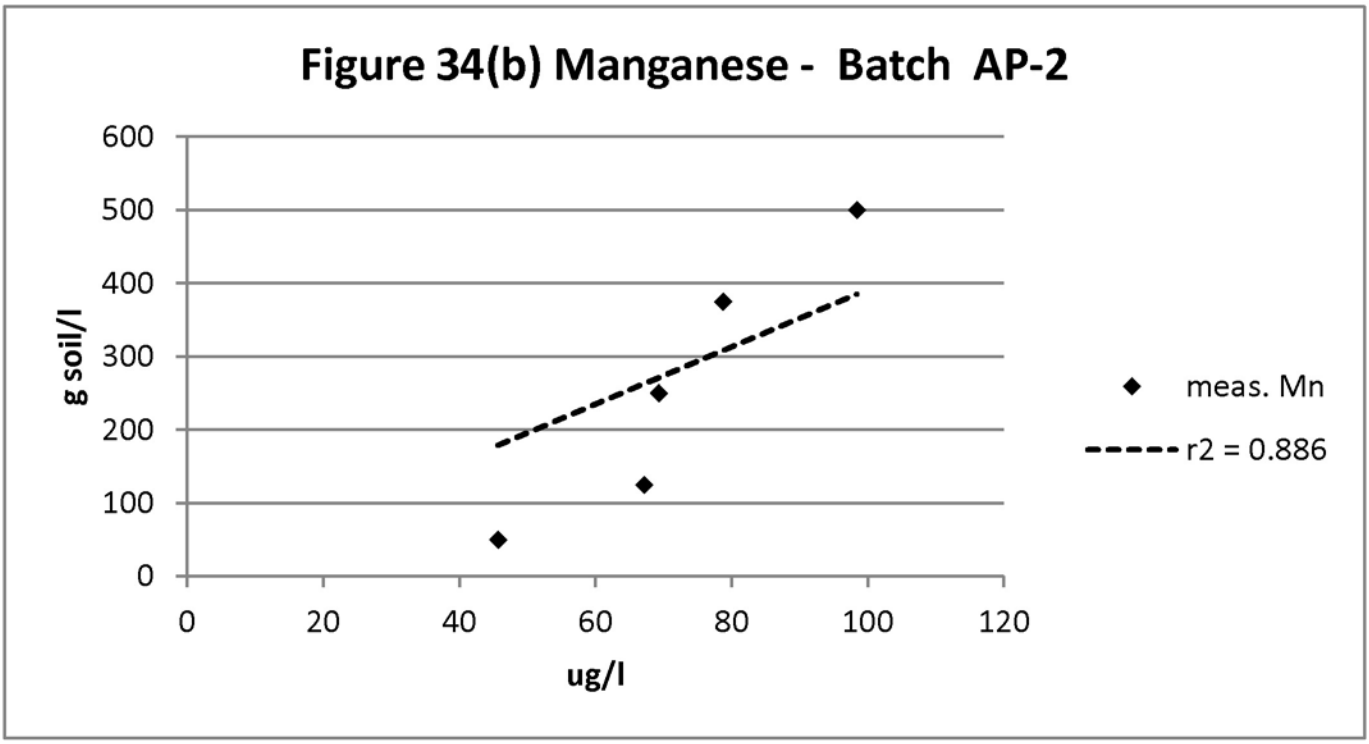


Figure 34(b) Manganese - Batch AP-2
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
100
120
ug/l
meas. Mn
r2 = 0.886

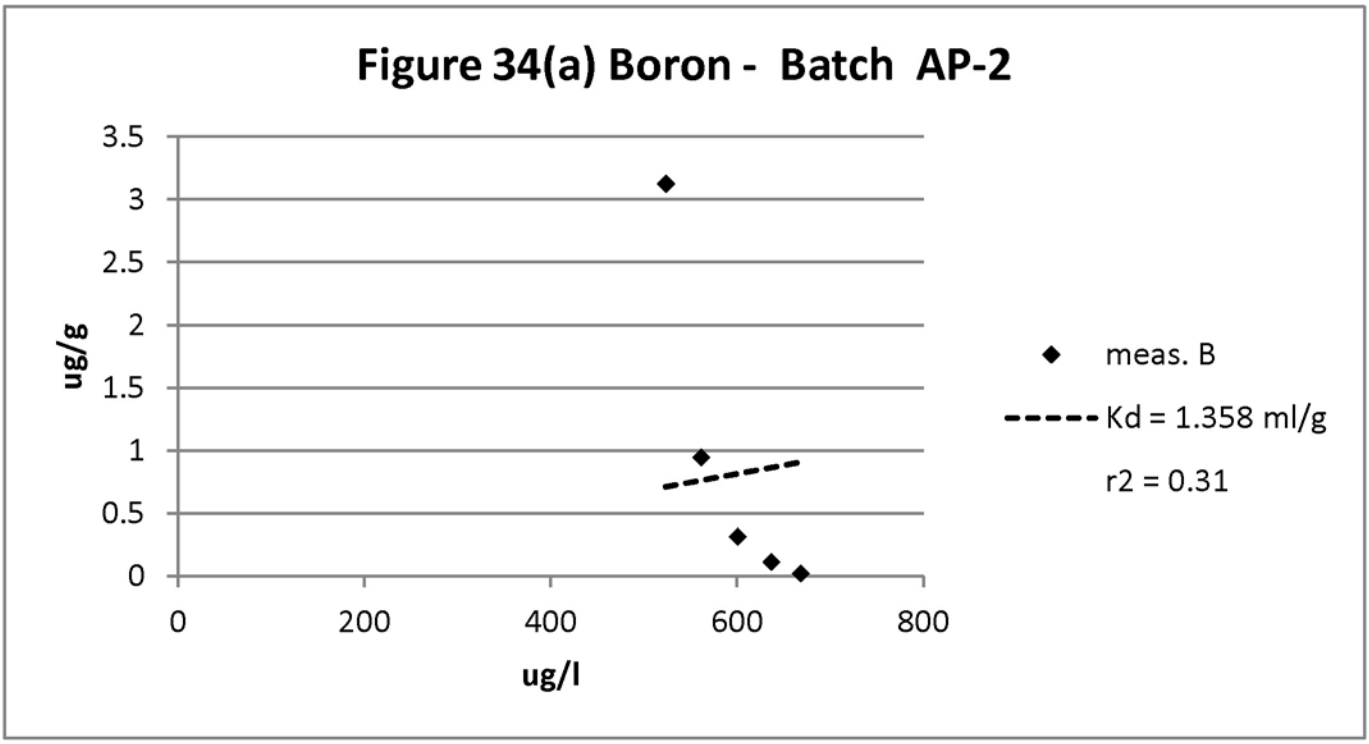


Figure 34(a) Boron - Batch AP-2
3.5
3
2.5
2
1.5
1
0.5
0
ug/g
0
200
400
600
800
ug/l
meas. B
Kd = 1.358 ml/g
r2 = 0.31

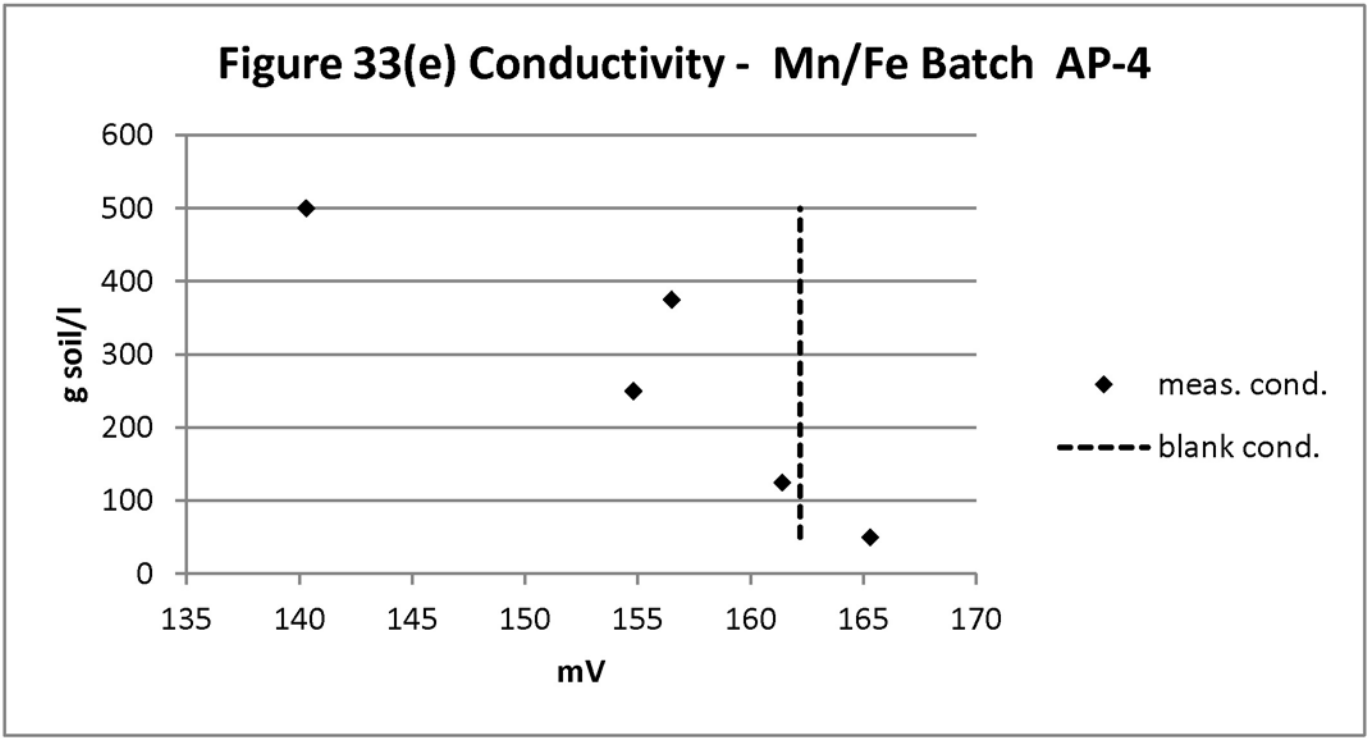


Figure 33(e) Conductivity - Mn/Fe Batch AP-4
600
500
400
300
200
100
0
g soil/l
135
140
145
150
155
160
165
170
mV
meas. cond.
blank cond.

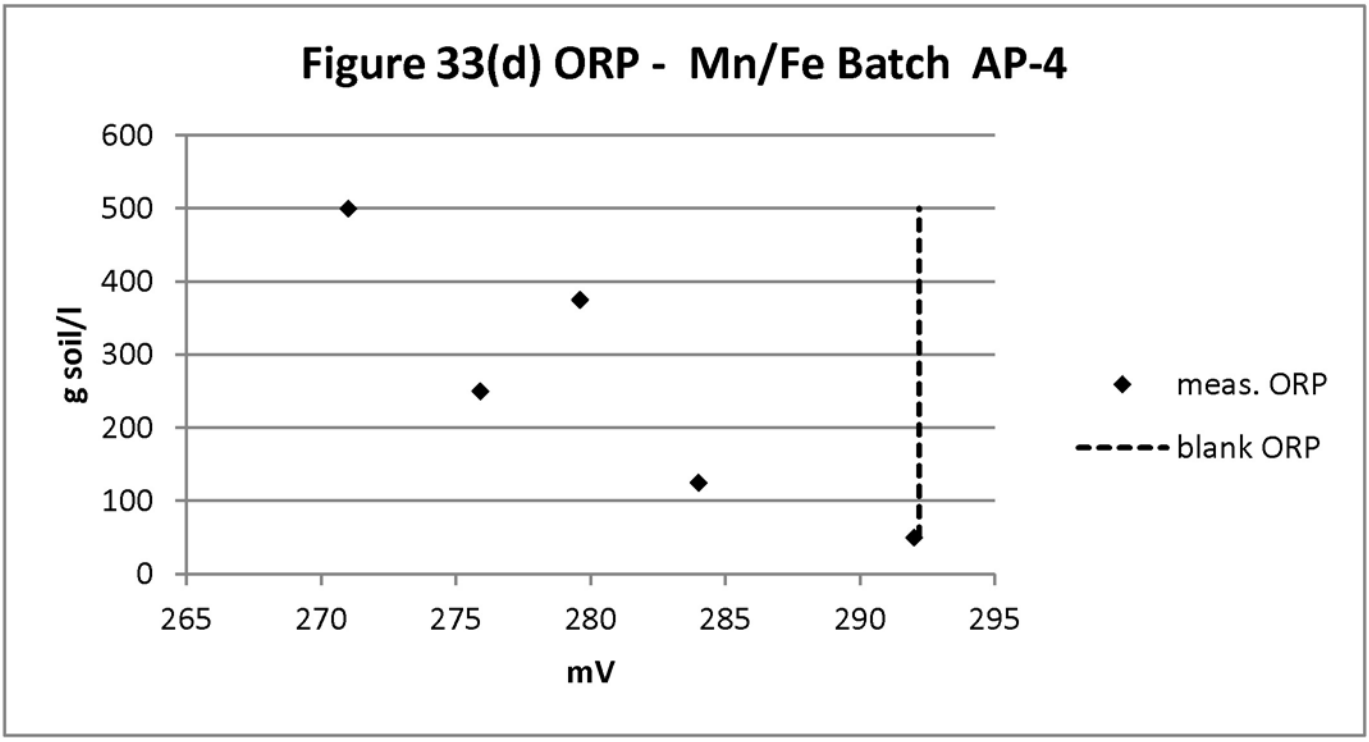


Figure 33(d) ORP - Mn/Fe Batch AP-4
600
500
400
300
200
100
0
g soil/l
265
270
275
280
285
290
295
mV
meas. ORP
blank ORP

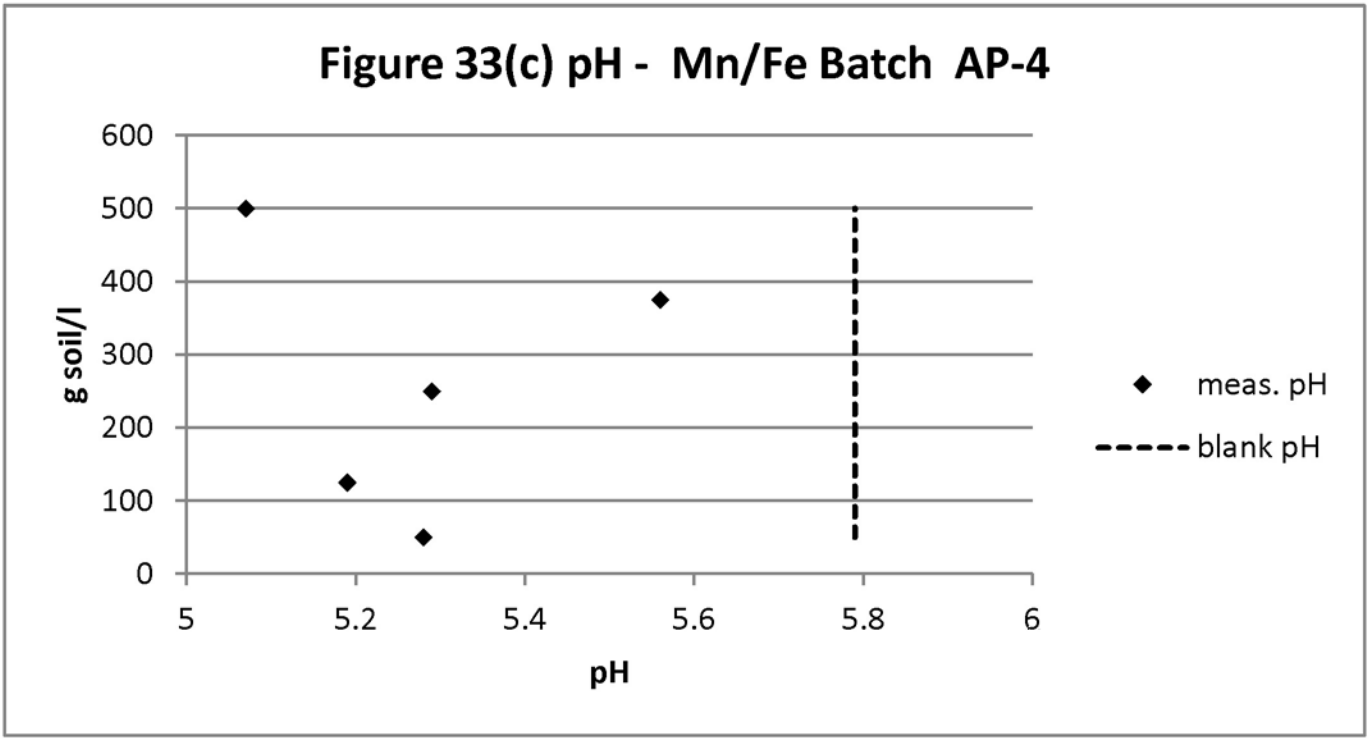


Figure 33(c) pH - Mn/Fe Batch AP-4
600
500
400
300
200
100
0
g soil/l
5
5.2
5.4
5.6
5.8
6
pH
meas. pH
blank pH

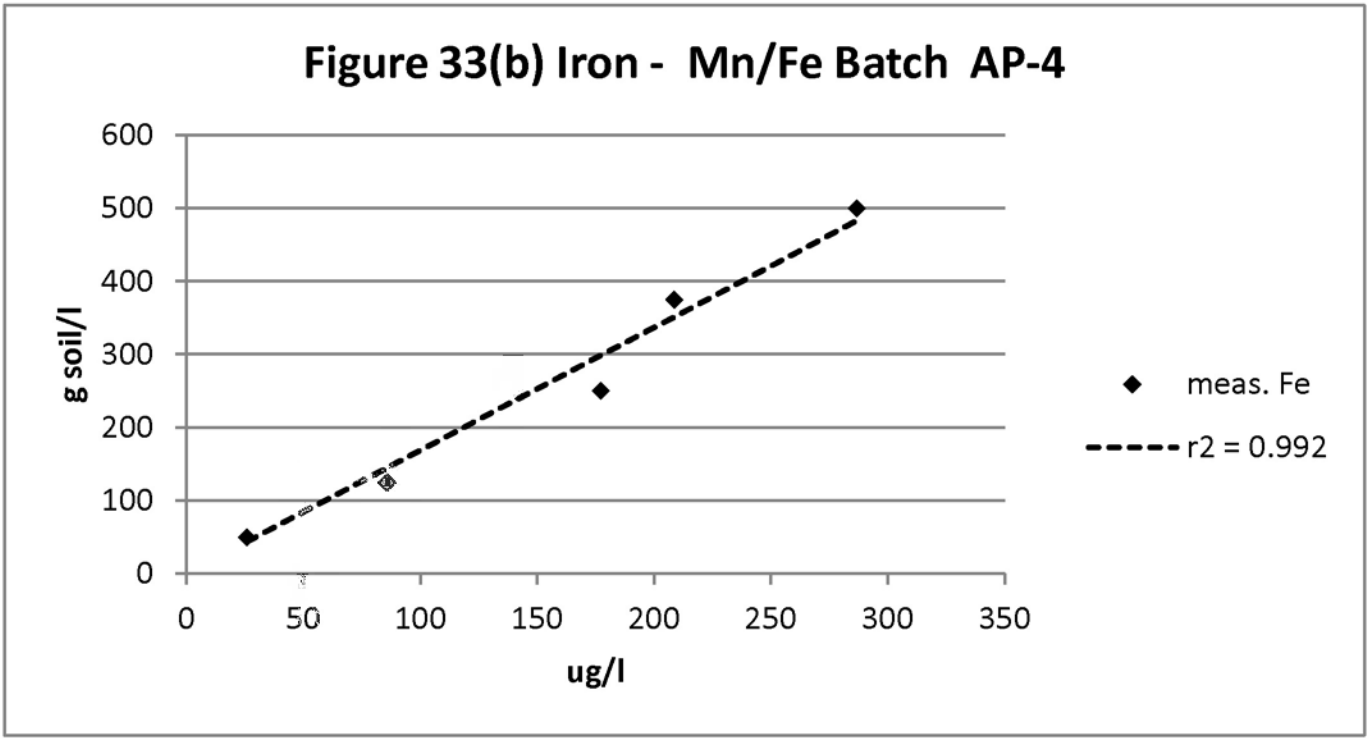


Figure 33(b) Iron - Mn/Fe Batch AP-4
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
250
300
350
ug/l
meas. Fe
r2 = 0.992

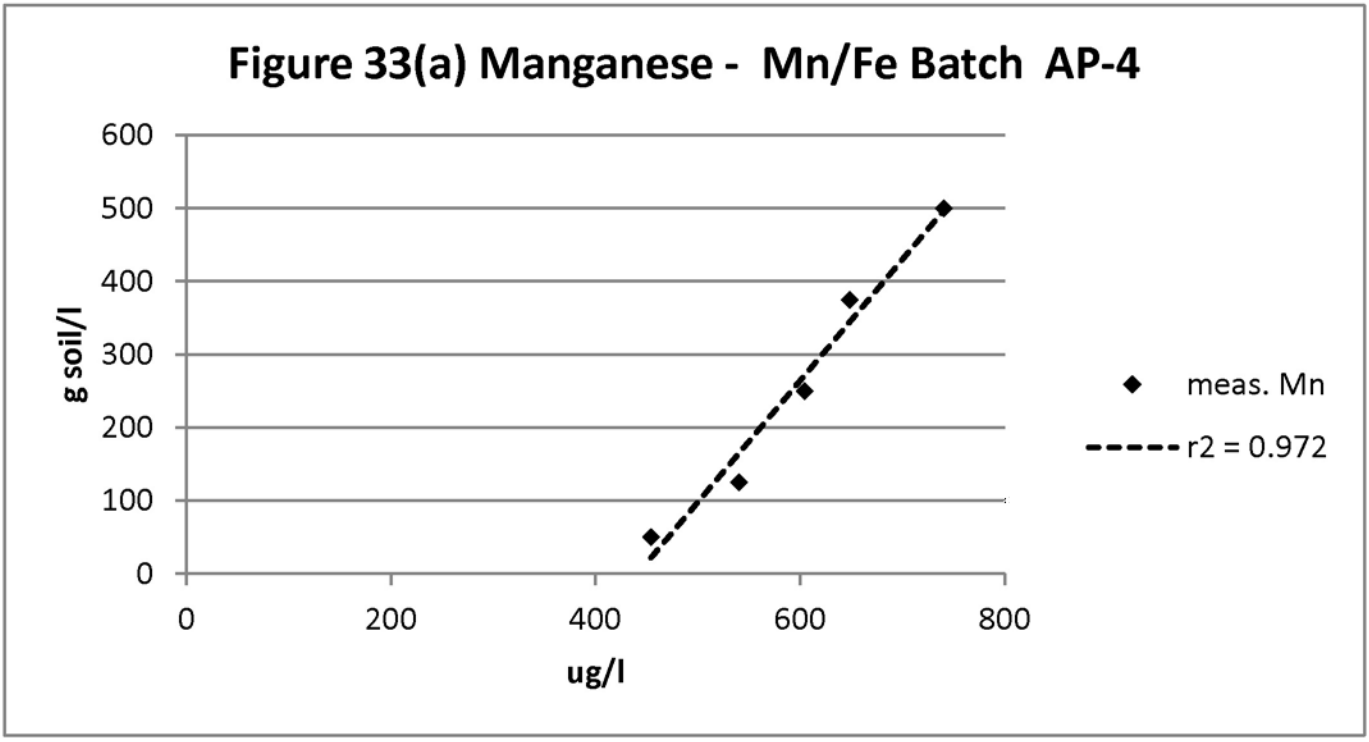


Figure 33(a) Manganese - Mn/Fe Batch AP-4
600
500
400
300
200
100
0
g soil/l
0
200
400
600
800
ug/l
meas. Mn
r2 = 0.972

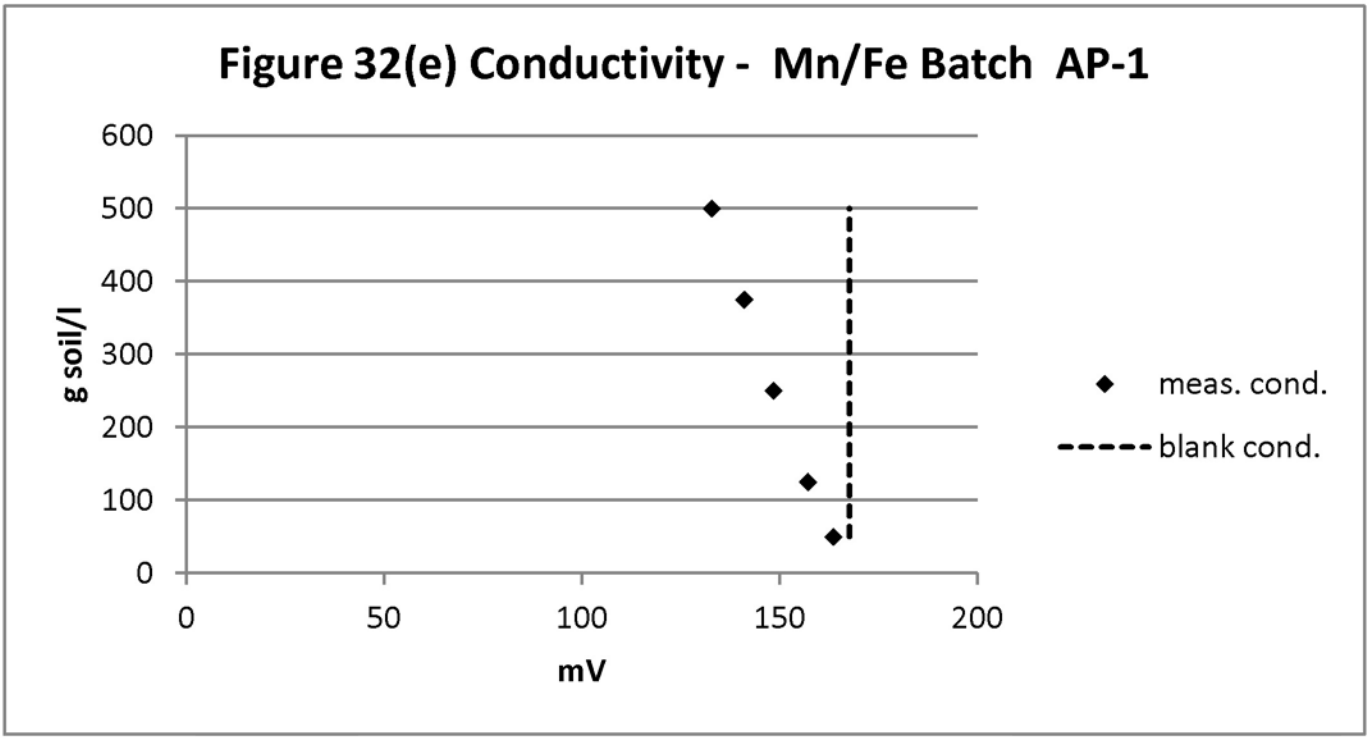


Figure 32(e) Conductivity - Mn/Fe Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
mV
meas. cond.
blank cond.

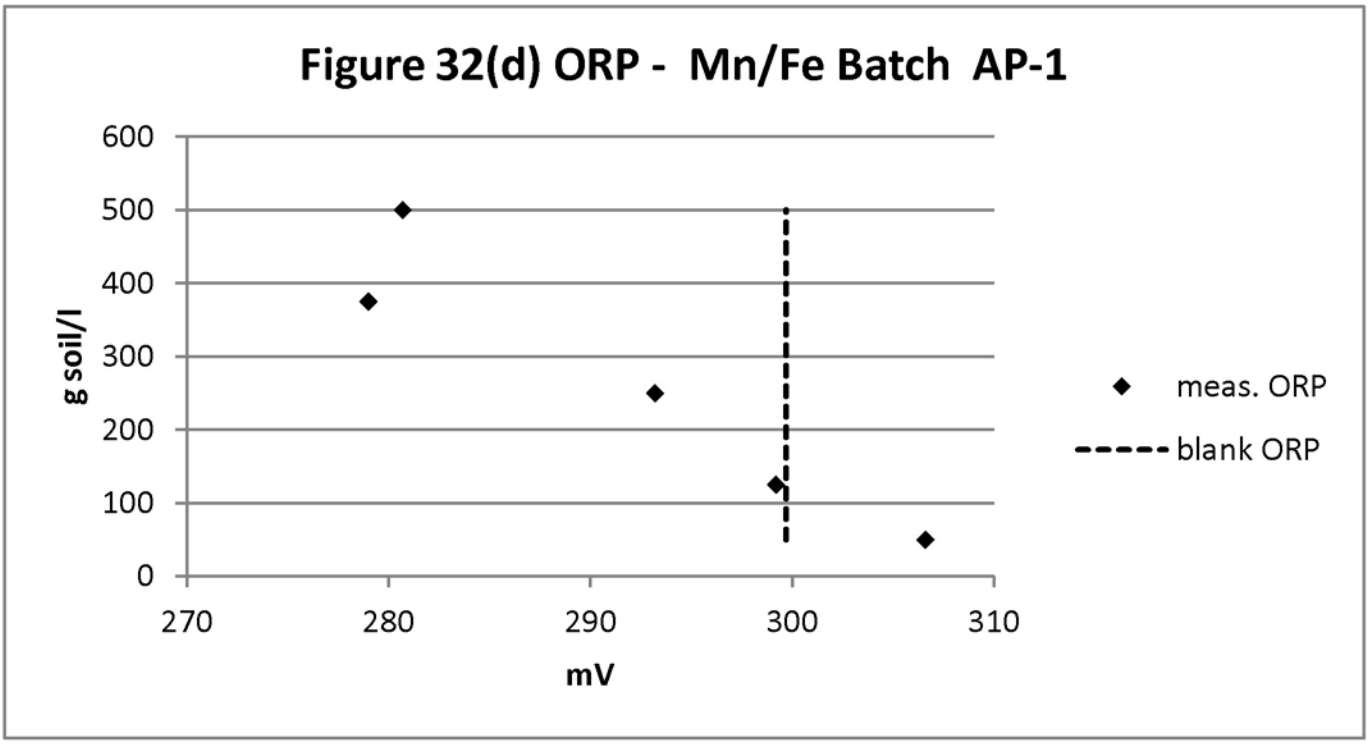


Figure 32(d) ORP - Mn/Fe Batch AP-1
600
500
400
300
200
100
0
g soil/l
270
280
290
300
310
mV
meas. ORP
blank ORP

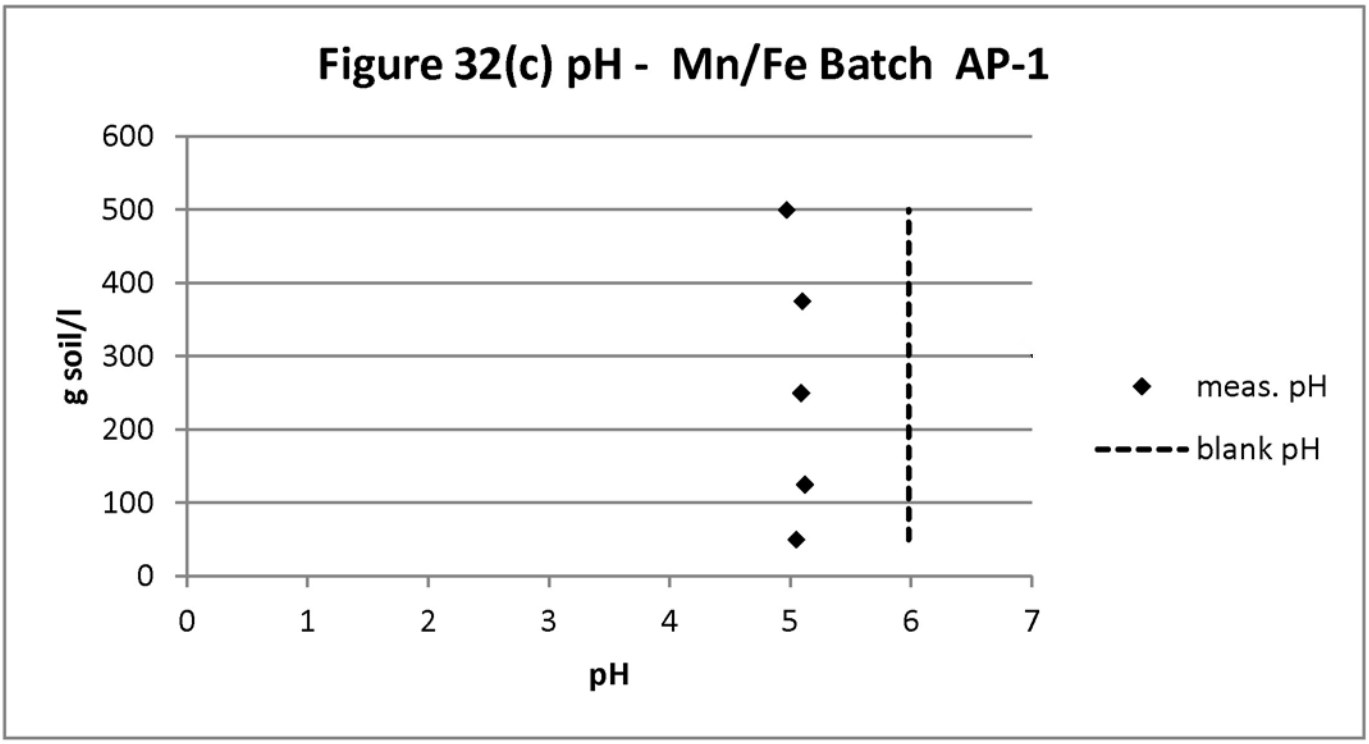


Figure 32(c) pH - Mn/Fe Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
1
2
3
4
5
6
7
pH
meas. pH
blank pH

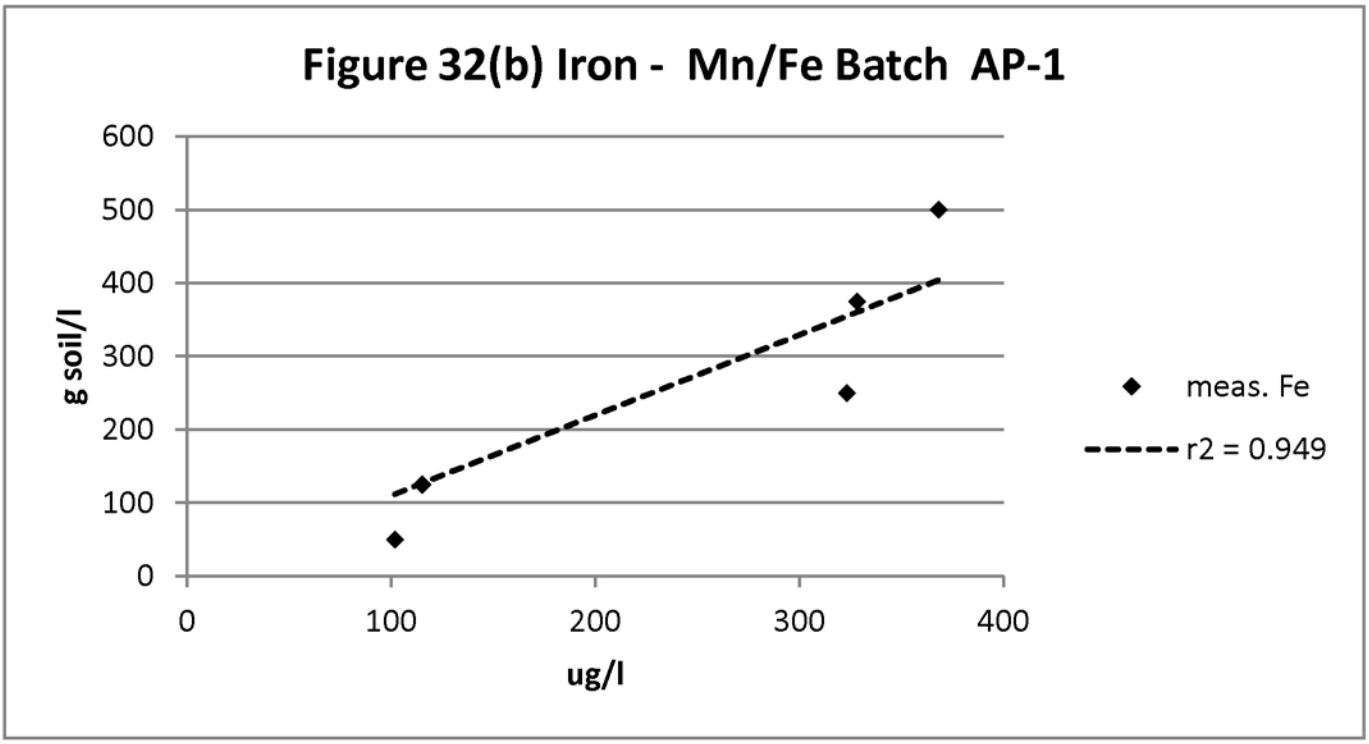


Figure 32(b) Iron - Mn/Fe Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
100
200
300
400
ug/l
meas. Fe
r2 = 0.949

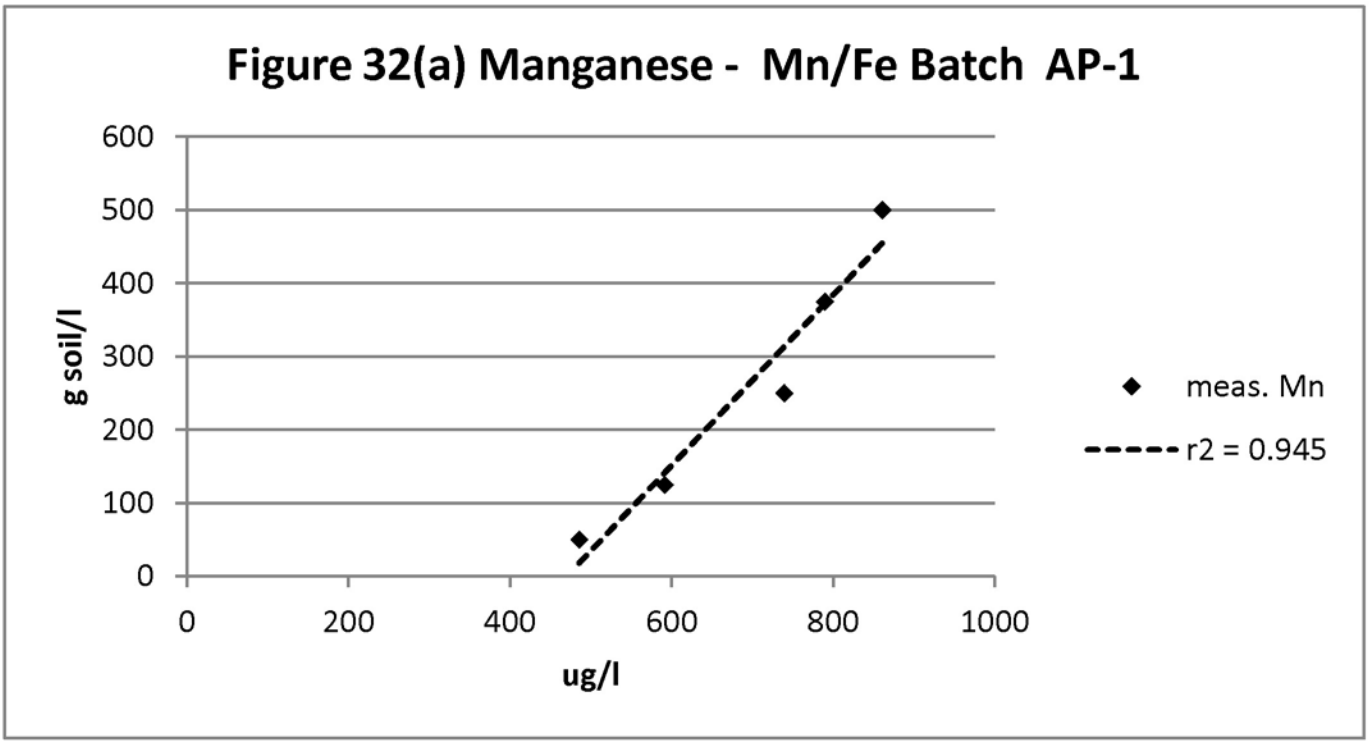


Figure 32(a) Manganese - Mn/Fe Batch AP-1
600
500
400
300
200
100
0
g soil/l
0
200
400
600
800
1000
ug/l
meas. Mn
r2 = 0.945

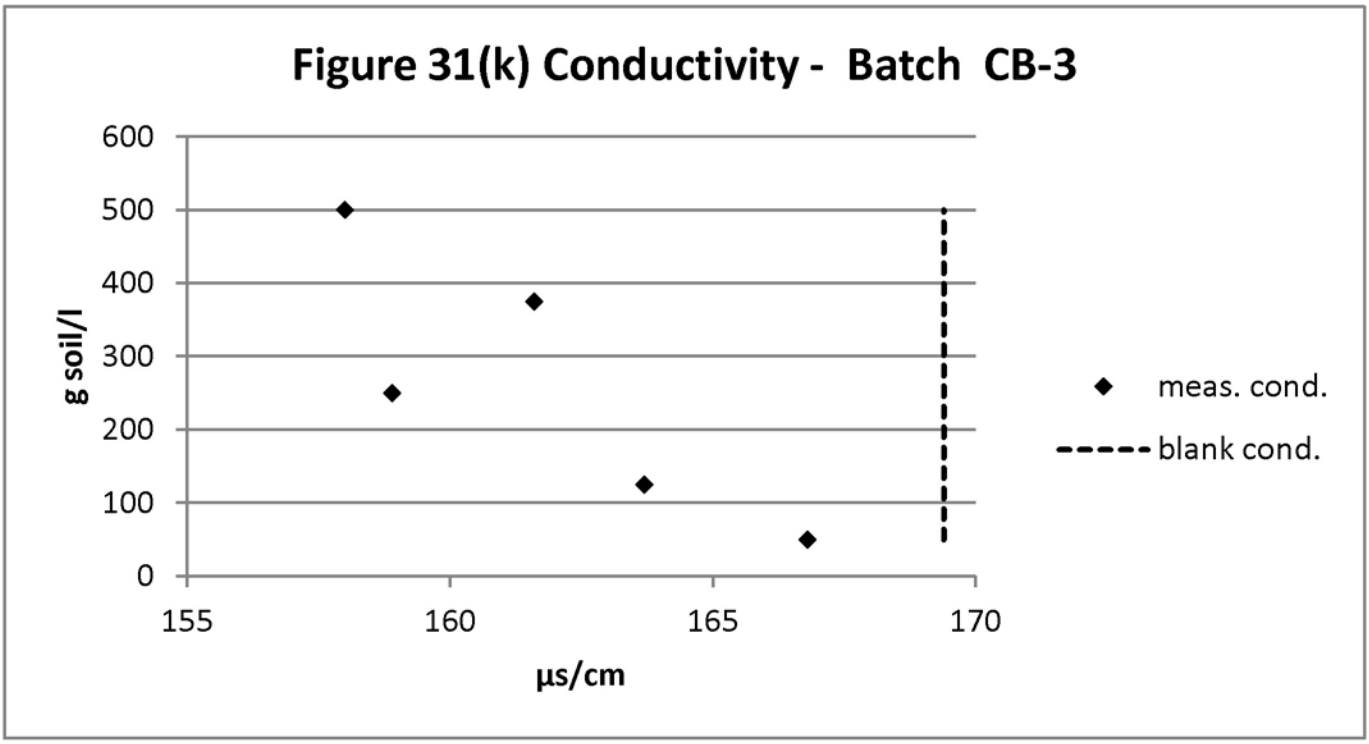


Figure 31(k) Conductivity - Batch CB-3
600
500
400
300
200
100
0
g soil/l
155
160
165
170
µs/cm
meas. cond.
blank cond.

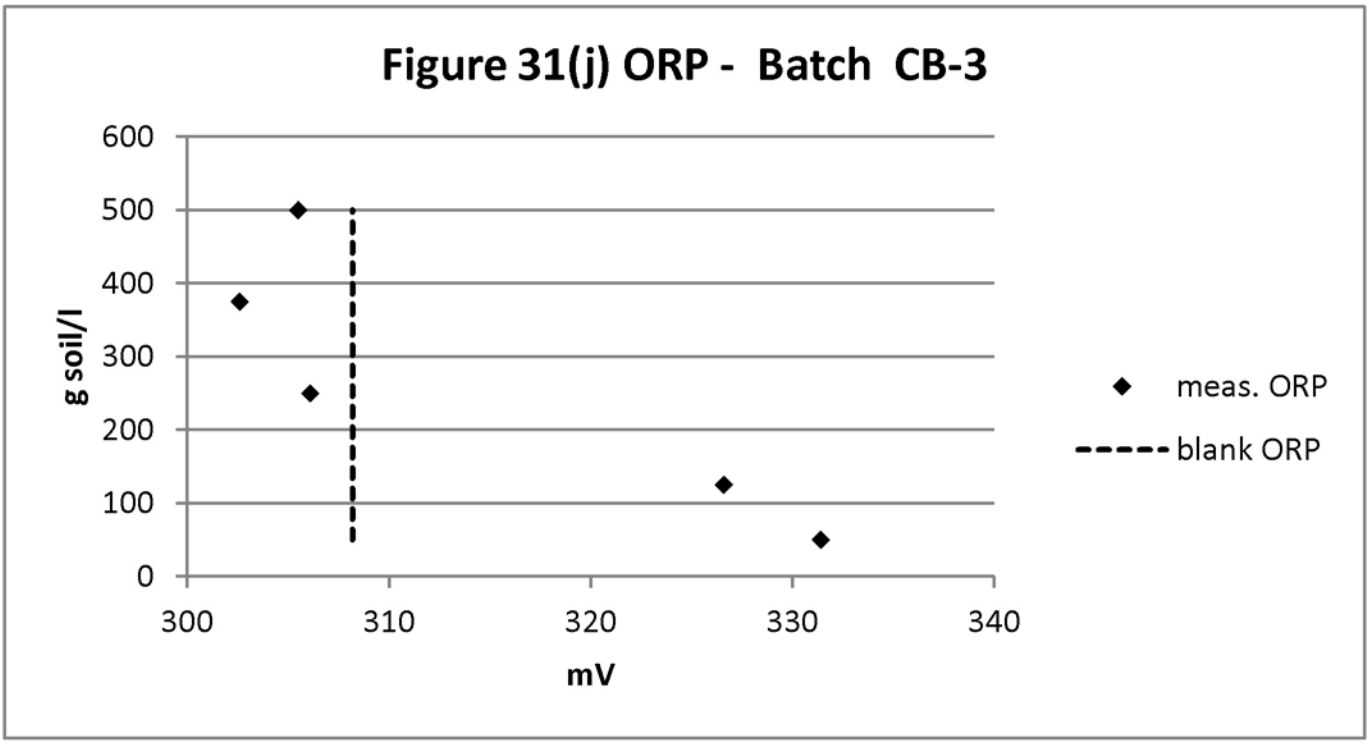


Figure 31(j) ORP - Batch CB-3
600
500
400
300
200
100
0
g soil/l
300
310
320
330
340
mV
meas. ORP
blank ORP

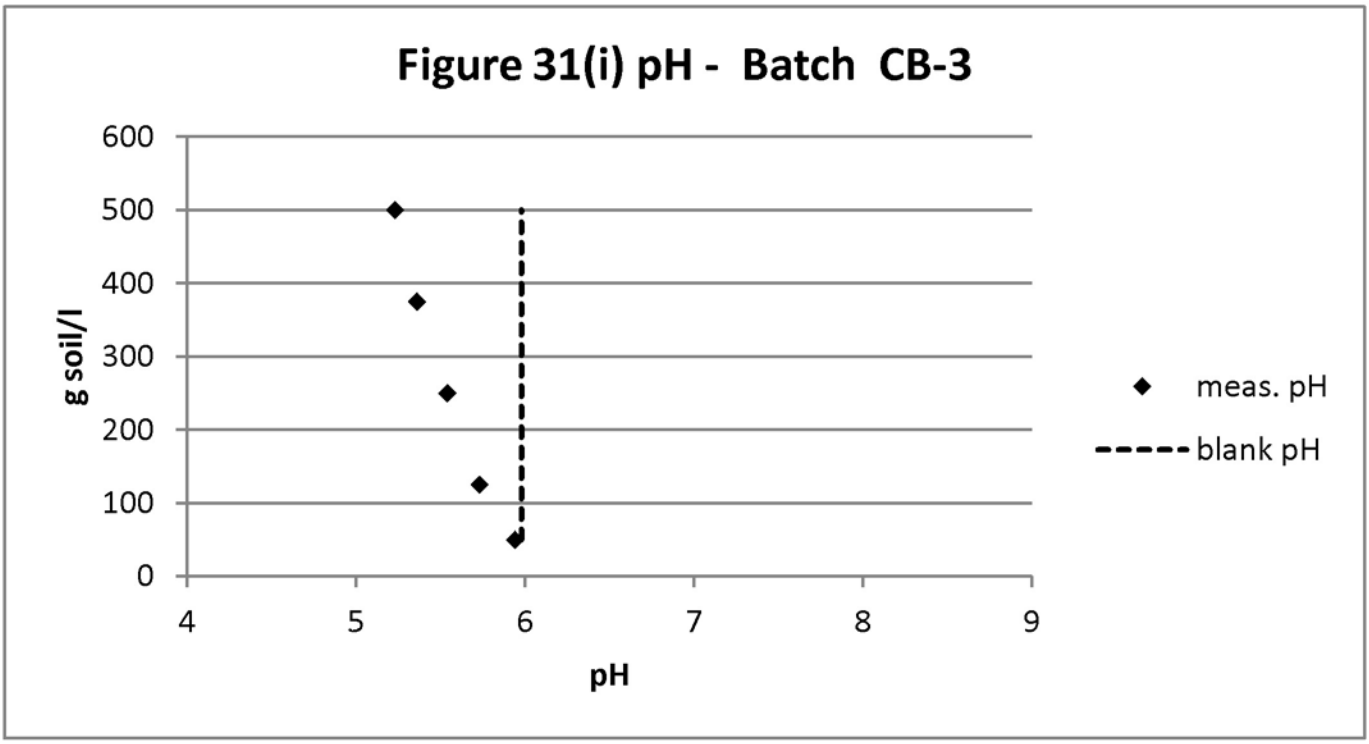


Figure 31(i) pH - Batch CB-3
600
500
400
300
200
100
0
g soil/l
4
5
6
7
8
9
pH
meas. pH
blank pH

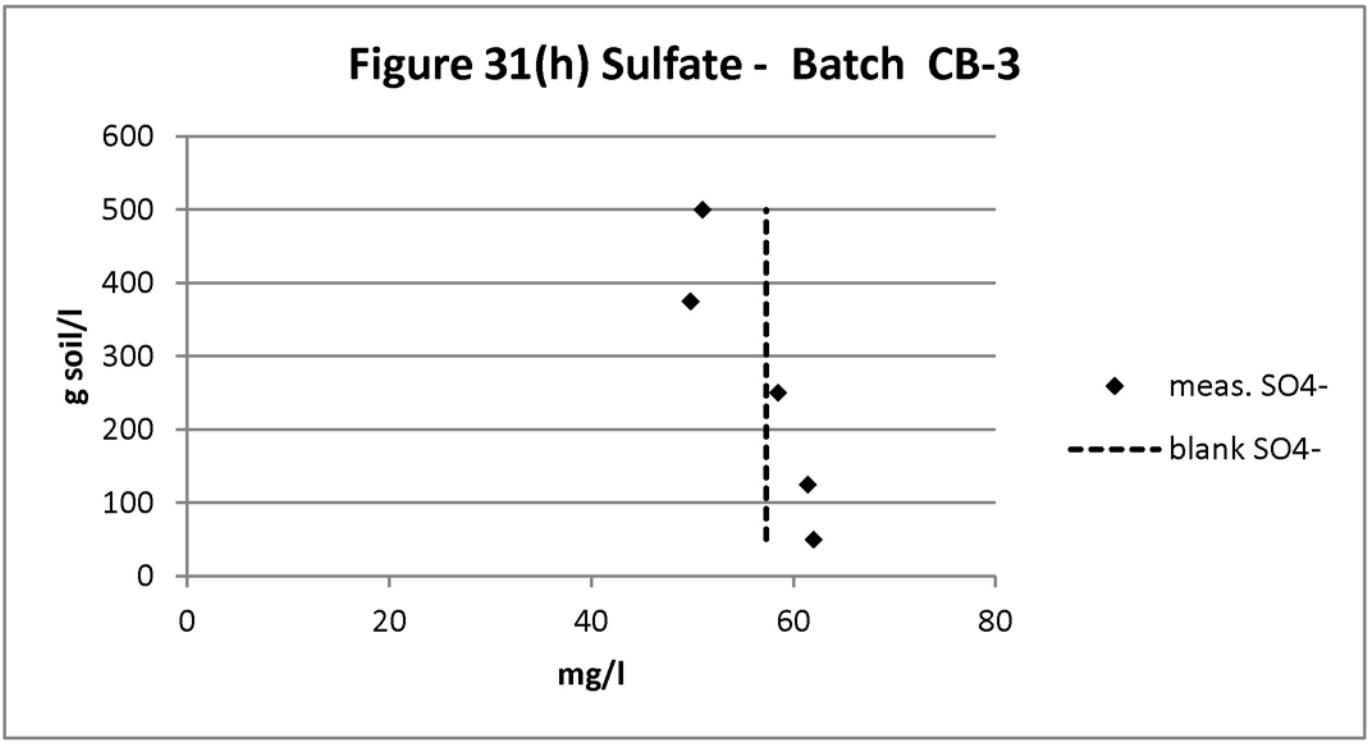


Figure 31(h) Sulfate - Batch CB-3
600
500
400
300
200
100
0
g soil/l
0
20
40
60
80
mg/l
meas. SO4-
blank SO4-

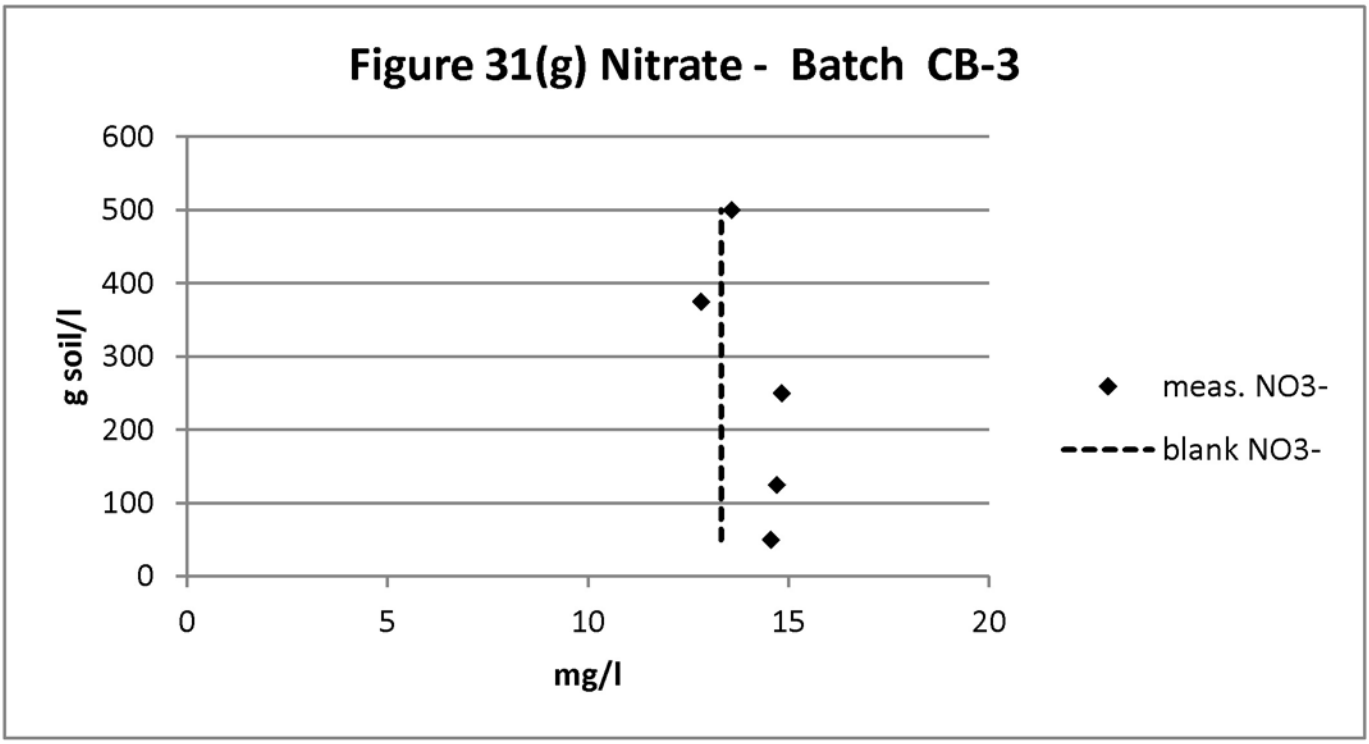


Figure 31(g) Nitrate - Batch CB-3
600
500
400
300
200
100
0
g soil/l
0
5
10
15
20
mg/l
meas. NO3-
blank NO3-

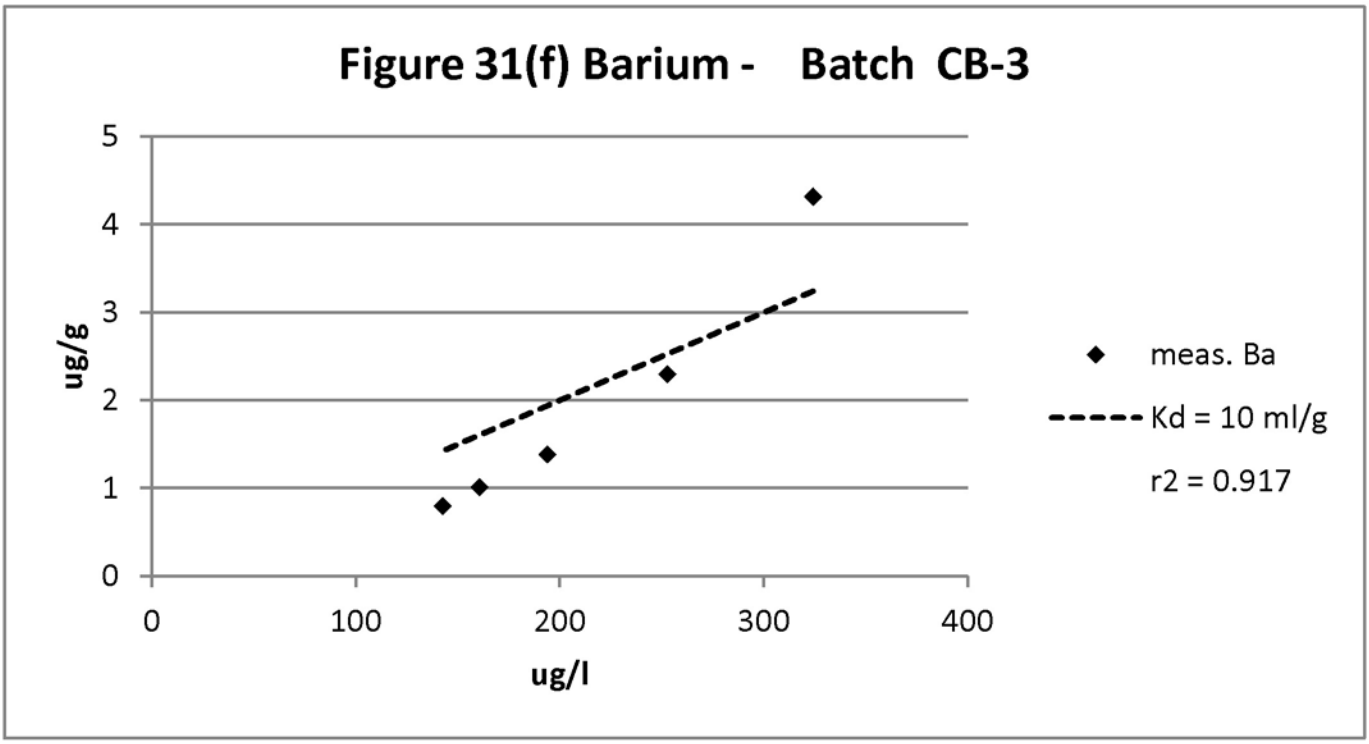


Figure 31(f) Barium - Batch CB-3
5
4
3
2
1
0
ug/g
0
100
200
300
400
ug/l
meas. Ba
Kd = 10 ml/g
r2 = 0.917

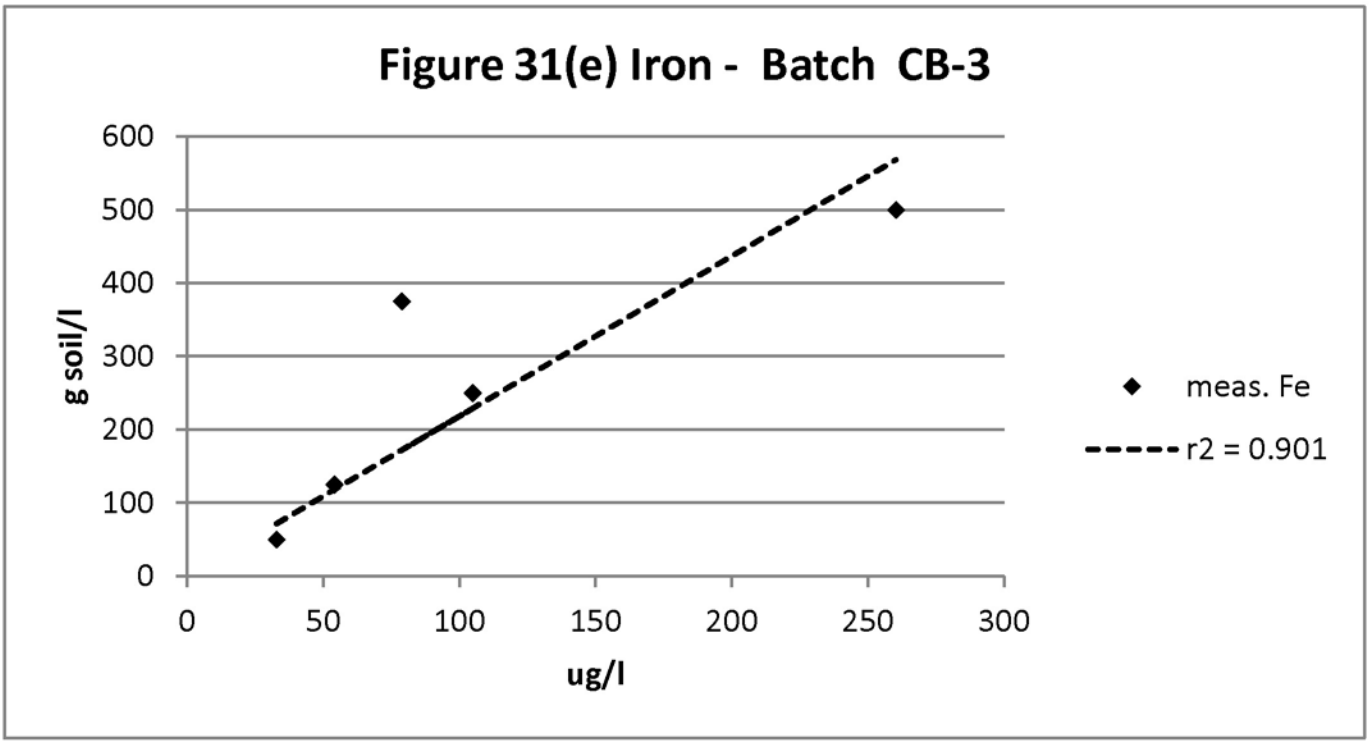


Figure 31(e) Iron - Batch CB-3
600
500
400
300
200
100
0
g soil/l
0
50
100
150
200
250
300
ug/l
meas. Fe
r2 = 0.901