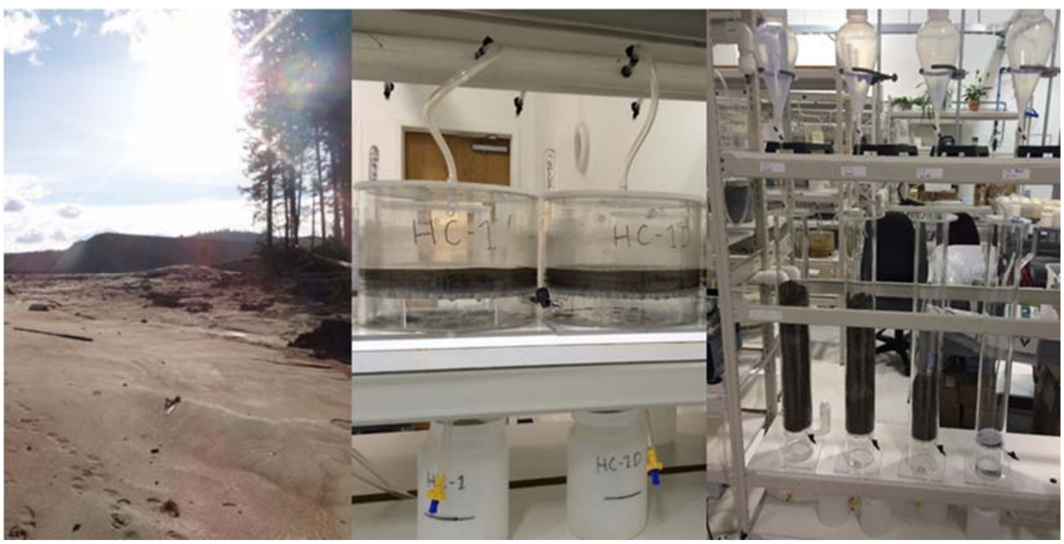
Mount Polley Mine Tailings Dam Failure: Update on Geochemical Characterization of Spilled Tailings

Prepared for

Mount Polley Mining Corp.



Prepared by

srk consulting

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SRK Consulting (Canada) Inc.
1CI008.003
November 2015

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Executive Summary

A geochemical characterization program was developed and carried out by SRK Consulting (Canada) Inc. on spilled tailings from the Mount Polley Mine (MPM) dam failure that occurred on August 4, 2014, approximately 55 km north-east of Williams Lake, BC. Initial results were provided in SRK (2015), with results pending for analysis of the non-sulphide fraction of the spilled tailings and laboratory kinetic testing (humidity cells and columns). This report provides the pending results, although kinetic testing is on-going.

Copper and selenium were the main focus of continued investigations as they were identified to be enriched in the initial study and possibly have potential for leaching. However, all parameters with guidelines for the protection of freshwater aquatic life in British Columbia are being monitored.

The non-sulphide copper analysis (i.e. a 2.5% sulphuric acid leach) indicated that up to 66% of the solid phase copper in the tailings materials is associated with the non-sulphide portion of the tailings. As extremely acidic conditions are required to leach this form of copper, it is considered to be non-reactive in the Hazeltine Creek environment because pH conditions are neutral and there is a low risk of acid rock drainage potential from the tailings.

Kinetic testing results have been reported for 32 weeks as of the date of this report. Results support the assessment that ARD is not expected from the tailings and leaching will be under neutral to alkaline conditions. Leaching rates are beginning to stabilize and general downward trends are expected to continue as the testing progresses. Variability in leaching rates is also being established and the necessary components for providing contact water chemistry predictions (i.e. geochemical source terms) will be available after testing passes 40 weeks.

One of the considerations for water chemistry prediction will be flow paths as copper and selenium leaching rate differences were noted between the humidity cells and columns. Mineral solubility limits for calcite (calcium carbonate) and tenorite (copper oxide) were reached in the columns but not in the humidity cells, with the formation of secondary copper minerals expected to limit concentrations of copper. Selenium is not expected to have a mineral solubility control under fully oxygenated conditions, but the longer water flow paths in fine grained materials may also be conducive to lower rates of oxygen diffusion and, therefore, conditions that support selenium reduction to more insoluble forms such as selenite and elemental selenium.

Kinetic testing is on-going and the current assessment of tailings reactivity and leaching rates will be updated once testing passes 40 weeks.

Table of Contents

List of Figures

List of Tables

Appendices

List of Abbreviations

ABA	acid-based accounting
ARD	acid rock drainage
DOC	dissolved organic carbon
HC	humidity cells
ICP-MS	inductively coupled plasma mass spectrometry
IGCM	initial geochemical conceptual model
LOD	limit of detection
ML/ARD	metal leaching and acid rock drainage
MPM	Mount Polley Mine
MPMC	Mount Polley Mining Corporation
ORP	oxidation-reduction potentials
QA/QC	quality control and quality assurance
RPD	relative percentage difference
SI	saturation indices
TIC	total inorganic carbon

1 Introduction

SRK was retained by the Mount Polley Mining Corporation (MPMC) to develop and execute a plan to geochemically characterize tailings materials that were released as a result of the tailings dam failure on August 4, 2014 from the Mount Polley Mine (MPM), located approximately 55 km north-east of Williams Lake, BC. The plan included a review of existing operational data, development of a geochemical conceptual model to guide sampling design, and a sampling and analysis plan.

The majority of geochemical characterization work has been completed with interpretation of results previously reported by SRK (2015). The work presented in this report that was not previously reported includes characterization of the non-sulphide component of the tailings and laboratory kinetic testing results (i.e. humidity cells and water unsaturated columns). This report is a supporting document to the initial work and provides updates to the conclusions provided in the SRK (2015) report on the metal leaching and acid rock drainage (MLARD) potential of exposed tailings along Hazeltine Creek.

2 Background

Geochemical characterization, including acid-base accounting (ABA) tests, trace element analyses, mineralogical analyses, and sequential extractions were undertaken on representative samples of tailings that spilled into Hazeltine Creek, and Quesnel and Polley Lakes from the MPM. The characterization approach was based on SRK's sampling plan (SRK 2014) and the geochemical conceptual models presented along with complete details on the sampling and analytical methods used, field observations and analytical results are provided in SRK (2015). For ease of reference, relevant sections have been reproduced in this report.

Two types of tailings-bearing materials were observed along Hazeltine Creek. They were classified in the field as 'grey tailings' and 'magnetite sands'. Grey tailings were dominantly grey in colour and had a finer texture (silty sand) than the magnetite sands. Magnetite sands were speckled pinkish-orange and black. They were strongly magnetic and sandier than the grey tailings. The grey tailings tended to be most abundant along the embankments and upper benches of the creek, whereas the magnetite sands were commonly present in low-lying areas near the creek. With the exception of the area near the tailings dam failure and Polley Lake, the tailings were deposited in relatively thin 'skiffs' (e.g. 10 to 20 cm deep). The thickest observed tailings deposits (e.g. around 1 metre deep) were in the immediate vicinity of the tailings dam failure and Polley Lake (SRK 2015).

The main geochemical finding was that the MPM tailings are not potentially ARD generating, which is consistent with historical understanding of the tailings and the low sulphur nature of the ore deposit. Any leaching would be expected to occur under neutral to basic pH conditions only, which tends to support low mineral and element specific solubility. The only elements that were noted to be enriched when compared to typical crustal rocks (basalt) were copper and selenium. Both of these elements were expected to be associated with sulphide minerals and require oxidation to be leached. The potential for reductive dissolution processes to leach elements from natural oxidation components of the spilled tailings that settled in Quesnel and Polley Lakes was assessed and found to be low.

The main questions/tasks remaining after the initial characterization report were:

- Confirm if copper is partially deported to non-sulphide minerals (also referred to by MPM as copper ‘oxide’).
- Characterize leaching rates of the spilled tailings.

Establishing the proportion of copper and other elements associated with the non-sulphide fraction is important as they are not likely to readily leach from the tailings at neutral pH. Leaching rates of the tailings have been assumed to be low, but need to be demonstrated and are an important consideration for assessing potential water chemistry changes arising from the tailings in the receiving environment.

3 Methods

3.1 Non-Sulphide Copper Analysis

Approximately 25% (17 out of 69) of the Hazeltine Creek tailings materials collected in the field between September 8, 2014 and September 19, 2014 were submitted for determination of copper and other elements associated with the non-sulphide fraction. Samples were selected to capture the range of sulphur, total inorganic carbon (TIC), copper, and selenium content in the Hazeltine Creek samples based on previous results (SRK 2015).

Determination of non-sulphide copper was performed by ALS Environmental based on a similar method routinely used by MPM on-site as follows:

- Leach dried samples with 2.5% sulphuric acid (H_2SO_4).
- Mix the acidic slurry using a vortex shaker and then on a shaker table for 90 minutes.
- Collect supernatant after settling, filter and submit for ICP-MS multi-element scans (35 elements including sulphur and low level selenium).

The main difference from the MPM method is that ICP-MS was used instead of atomic absorption spectroscopy. Two samples were randomly selected to serve as duplicates for QA/QC purposes.

3.2 Kinetic Testing

3.2.1 General

The kinetic testing program consists of six standard laboratory humidity cells (HCs), three column leach tests, two blanks (a HC and a column), and one HC duplicate (Table 3-1). Samples were selected to represent the median and upper range of geochemical variability identified during the initial characterization work.

The intent of the program is to establish weathering rates under atmospheric conditions using humidity cell testing and then use column tests to evaluate the effect of longer water flow paths. Longer flows paths are more likely to represent field conditions and to assess potential attenuation processes such as formation of secondary minerals and surface sorption.

Geochemical composition and mineralogy characteristics were obtained during the initial characterization work and results are summarized in Section 4.3 for ease of reference.

Table 3-1: Composite preparation requirements and sample labelling.

Kinetic Test ID	Tailings Type	Original Sample IDs (SRK 2015)
HC-1/COL-1; HC-1D	Magnetite Sand	Composite of ST11-02-02, ST12-02 and ST11-02-1
HC-2/COL2	Magnetite Sand	Composite of ST16-02 and ST01-03
HC-3/COL-3	Grey Tailings	Composite of ST08-02-01 and ST13-03
HC-4	Grey Tailings	ST01-05-02
HC-5	Magnetite Sand	ST02-05-02
HC-6	Grey Tailings	ST17-08-01
HC-7	Blank	
COL-4		

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3.2.2 Humidity Cells

The HCs were set up according to the methods described in the 1991 Mine Environment Neutral Drainage Program's Acid Rock Drainage Prediction Manual (MEND 1991). A photograph of the set-up is provided in Figure 3-1.

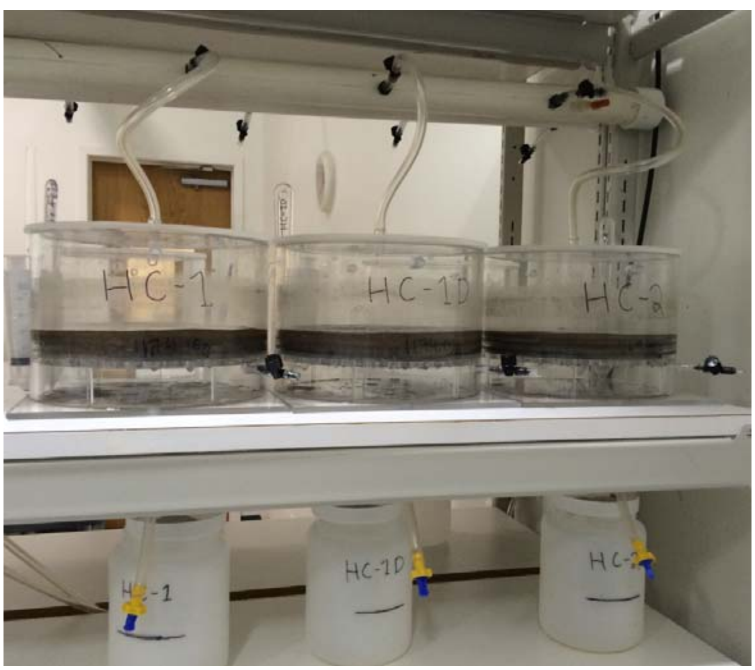

Figure 3-1: Set-up of tailings humidity cells at ALS Environmental. For scale, the diameter of the clear plastic cells is 20 cm.

The two major sample mixture/tailings types identified in the field, (1) magnetite sands tailings and (2) grey tailings, were both tested. The duplicate cell (HC-1D) is a split from HC-1. The blank cell (HC-7) was constructed using the exact same material and adhesives as the other cells and is operating according to the same procedures.

Weekly analyses of leachate included volume recovered, pH, and conductivity.

The following parameters were measured weekly for the first four weeks and then every two weeks thereafter:

- Acidity, alkalinity
- Oxidation-reduction potential (ORP)
- Sulphate
- Nitrate, nitrite, ammonia
- Bromide, chloride, fluoride
- Orthophosphate, total phosphorus
- 35 element scan by ICP-MS
- Low level mercury

The tests were initiated on March 6, 2015, and have yielded 32 weeks of data at the time the data were interpreted for this report. While these tests typically run for a minimum of 40 weeks, release rates are now stable and initial interpretations are provided herein. All tests are continuing.

3.2.3 Columns

The column tests, including the blank, were constructed from plexiglass (acrylic) with an 8.2 cm inner diameter and a perforated base supporting two layers of nylon screen (400 mesh). The columns were filled as follows:

- Column 1 (magnetite sand): 4.3 kg to a height of 45 cm
- Column 2 (magnetite sand): 4.5 kg to a height of 36 cm
- Column 3 (grey tailings): 1.5 kg to a height of 16 cm

ALS Environmental confirmed that heavier Column 2 had a lower height than Column 1, which is attributed to greater compaction compared to the other columns.

Each of the samples is being trickle leached. Columns 1 and 2 have about 90 mL added daily until 500 mL has been added in a work week (5 days). For Column 3, only 30 mL of water can be added in a day to avoid pooling on the surface and, as a result, only 150 mL is added in a week. Collection of leachate from the magnetite sands is performed weekly, whereas collection of leachate from the grey tailings column requires up to three weeks due to the fine grained nature of these materials resulting in slow infiltration rates. Laboratory analysis of leachate includes the same parameters as the humidity cells (Section 3.2.2). A photograph of the set-up is provided in Figure 3-2.

The tests were initiated on April 21, 2015. The magnetite sands samples have yielded 25 weeks of data, and the grey tailings 8 weeks of data at the time the data were interpreted for this report.

Figure 3-2: Column set-up at ALS Environmental. For scale, the diameter of the columns is 8 cm and the height of materials in column 1 (far left) is 45 cm.

4 Results

4.1 Quality Assurance and Quality Control

Various quality control and quality assurance (QA/QC) measures were included in the program. Duplicate comparisons were done for the non-sulphide copper analysis and kinetic tests. For the kinetic tests only, ion balance calculations and blank sample analysis were also done. Results were as follows:

- Duplicates – samples were assessed with a relative percent difference (RPD) target of 25% (set by SRK) when results were greater than ten times the limit of detection. RPD was calculated using the equation below, where ‘x’ is the concentration of the original sample and ‘y’ is the concentration from the duplicate sample:

$$RPD(\%) = \frac{x - y}{(x + y)/2} \times 100$$

- The RPD criterion does not apply at concentrations near the LOD because RPD is expected to frequently be greater than 25% due to reduced analytical accuracy at very low concentrations. This applied to silver and boron. All other parameters with guidelines for the protection of freshwater aquatic life in British Columbia (BC FAL guidelines) were within the criterion. Results for non-sulphide copper analysis for provided in Appendix A and duplicate humidity cell results are included in Appendix C.
- Ion balance – samples were assessed with an RPD target of ±15% (set by SRK) when major anions and cations were greater than ten times analytical detection limits. For all sampling dates the ion balance was within ±15%.
- Blanks – samples were assessed with a target of ten times the detection limit (set by SRK). None of the samples exceeded this criterion.

SRK's overall conclusion is that data quality is acceptable.

4.2 Non-Sulphide Copper Analysis

Results of sulphuric acid leaching to determine the amount of non-sulphide copper and selenium are provided in Table 4-1. Analytical results are provided in Appendix A.

The main finding was that a significant portion of the copper in the tailings is associated with the non-sulphide fraction, ranging from 29% to 66% with an average of 46%. This finding is consistent with previous understanding of the non-sulphide copper fraction representing between 20% and 70% (Taplin 2002; Henry 2009) and mineral processing of the MPM ore, as sulphide flotation would preferentially remove sulphides and leave behind a higher portion of non-sulphide minerals.

Selenium was much lower in the non-sulphide fraction, ranging from 4% to 23%, with an average of 13% of the total fraction.

Table 4-1: Non-sulphide analysis results for copper and selenium.

Sample ID	Sample Type	Non-Sulphide Cu mg/kg	Non-Sulphide Se mg/kg	% of Total Cu %	% of Total Se %
HC-1/COL-1	Magnetite Sand Composite	400	0.18	29%	11%
HC-2/COL-2	Magnetite Sand Composite	440	0.21	49%	13%
HC-3/COL3	Grey Tailings Composite	590	0.30	64%	19%
ST03-04	Grey Tailings	520	0.26	56%	23%
ST02-02-01	Grey Tailings	170	0.037	30%	4%
ST02-05-02/HC-5	Magnetite Sand	290	0.092	41%	8%
ST01-05-02/HC-4	Grey Tailings	100	0.035	32%	4%
ST18-03-02	Grey Tailings/Magnetite Mix	740	0.23	50%	19%
ST17-08-01/HC-6	Grey Tailings	390	0.21	30%	12%
ST05-02-01	Magnetite/Grey Tailings Mix	320	0.12	49%	10%
ST08-03	Magnetite Sand	450	0.22	43%	14%
ST12-04	Grey Tailings	480	0.24	55%	14%
ST14-04	Grey Tailings	510	0.28	66%	23%
ST18-02-01	Grey Tailings/Magnetite Mix	370	0.23	39%	14%
ST18-05-01	Grey Tailings	430	0.23	48%	14%
Statistics	Minimum	100	0.035	29%	4%
	Mean	430	0.22	48%	14%
	Maximum	740	0.30	66%	23%

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Note: Results have been rounded to two significant figures.

4.3 Kinetic Testing

4.3.1 General

Geochemical properties of the humidity cells were provided in SRK (2015), but for ease of reference key properties are provided in Table 4-2 and complete results are provided in Appendix B. Copper, selenium and sulphur concentrations for kinetic test samples and the entire dataset are compared in Figure 4-1 and Figure 4-2.

Table 4-2: Geochemical properties of kinetic tests.

Kinetic Test	Tailings Type	TIC kg $CaCO_3$/t	Total S %	S^{2-} %	AP kg $CaCO_3$/t	TIC/AP ratio	Cu mg/kg	Se mg/kg
HC-1/COL-1	Magnetite Sand	25	0.26	0.27	8.4	3.0	1200	1.5
HC-1D	Magnetite Sand	-	0.27	0.27	8.4	-	1200	1.7
HC-2/COL-2	Magnetite Sand	18	0.16	0.15	4.7	3.8	950	1.3
HC-3/COL-3	Grey Tailings	33	0.16	0.15	4.7	7.0	940	1.6
HC-4	Grey Tailings	26	0.17	0.09	2.8	9.3	320	0.9
HC-5	Magnetite Sand	15	0.18	0.13	4.1	3.6	720	1.2
HC-6	Grey Tailings	32	0.21	0.23	7.2	4.5	1300	1.8

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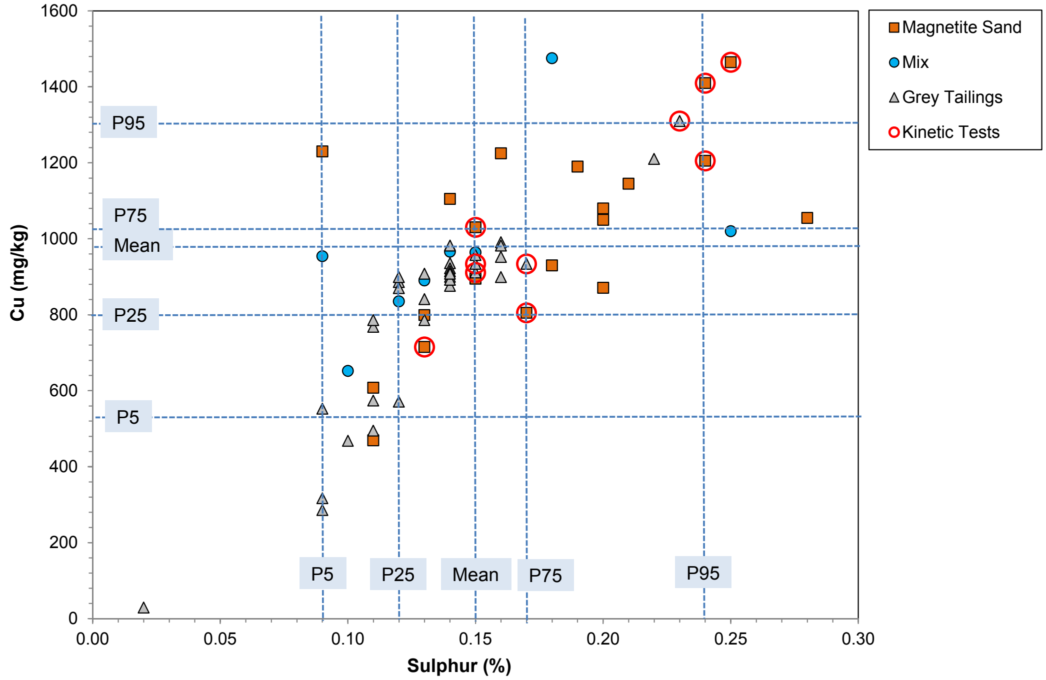

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Figure 4-1: Solid phase copper and sulphur concentrations in kinetic test selections compared to existing dataset.

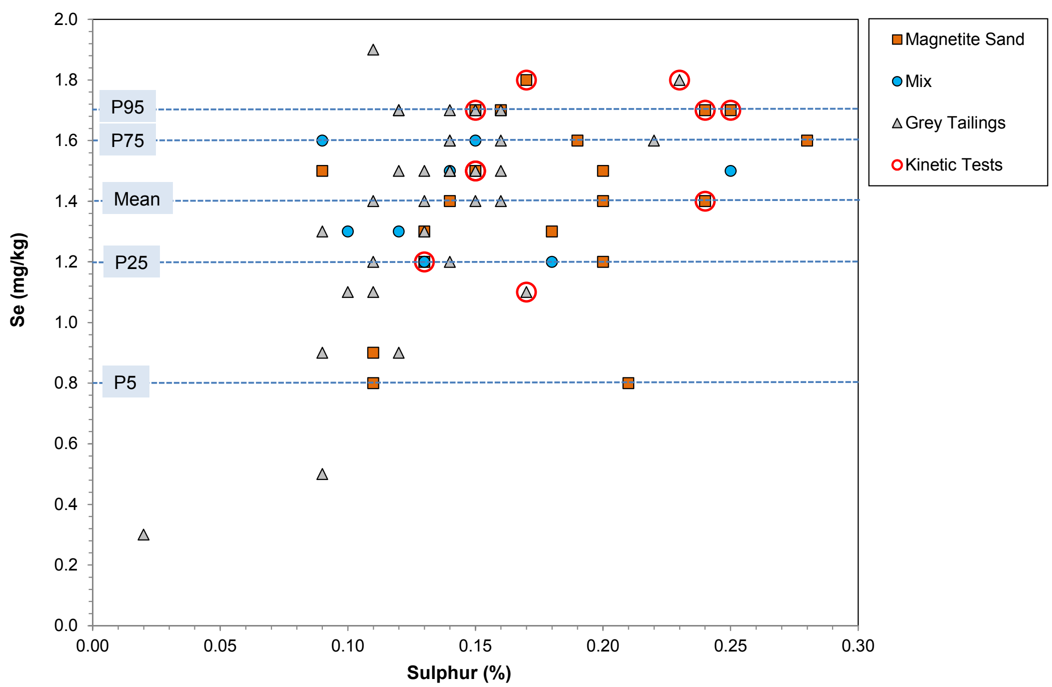

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Figure 4-2: Solid phase selenium and sulphur concentrations in kinetic test selections compared to existing dataset.

4.3.2 Humidity Cells

At the time of this report, data for 32 weeks had been received. Charts of humidity cells results for all parameters that have BC FAL guidelines are provided in Appendix C and a summary of leaching rates (loadings) are provided in Appendix D. Charts for pH and sulphate are provided in Figure 4-3 for ease of reference as these parameters are used to understand oxidation and leaching rates. Copper and selenium charts are also provided in Figure 4-3 as these are the two main elements noted to be of leaching concern by SRK (2015).

Humidity cell results for all parameters except pH are presented as loading rates in units of mg/kg/week. The laboratory data provides results as concentrations (i.e. mg/L), but given the known weight of each sample and a measured volume of water leached through the cells on a weekly basis, concentrations are converted to loadings.

Leachates from all humidity cell tests have shown alkaline pHs, just slightly above 8.0, and are dominated by sulphate, alkalinity (predicted to be bicarbonate), calcium and lesser amounts of magnesium, potassium and sodium. Release rates for major cations and trace elements have just begun to stabilize and are trending slightly down. Initially elevated sulphate was observed for most tests in the first few weeks of testing, which is typical of these tests reflecting flushing of oxidation products accumulated prior to testing.

The majority of tests are leaching at generally similar rates, with the exception of HC-4 (grey tailings). Copper is leaching at the highest rate in this test (HC-4) whereas selenium is leaching at the lowest rate for this sample. This is not consistent with the solid phase content of copper (Figure 4-4) nor with the significant correlation previously established by SRK (2015) between copper and selenium in the tailings. The solid phase correlation would indicate that selenium should also be leaching at the highest rate in HC-4, but instead it is leaching at the lowest rate (Figure 4-5). The tests are all yielding alkaline leachates (around pH 8), which typically supports low solubility of copper and with no pH difference between the tests. Other parameters that appear to be inconsistent in HC-4 are the relatively elevated nitrate, nitrite and iron (Appendix C). Investigations are on-going to understand the leaching behaviour in HC-4.

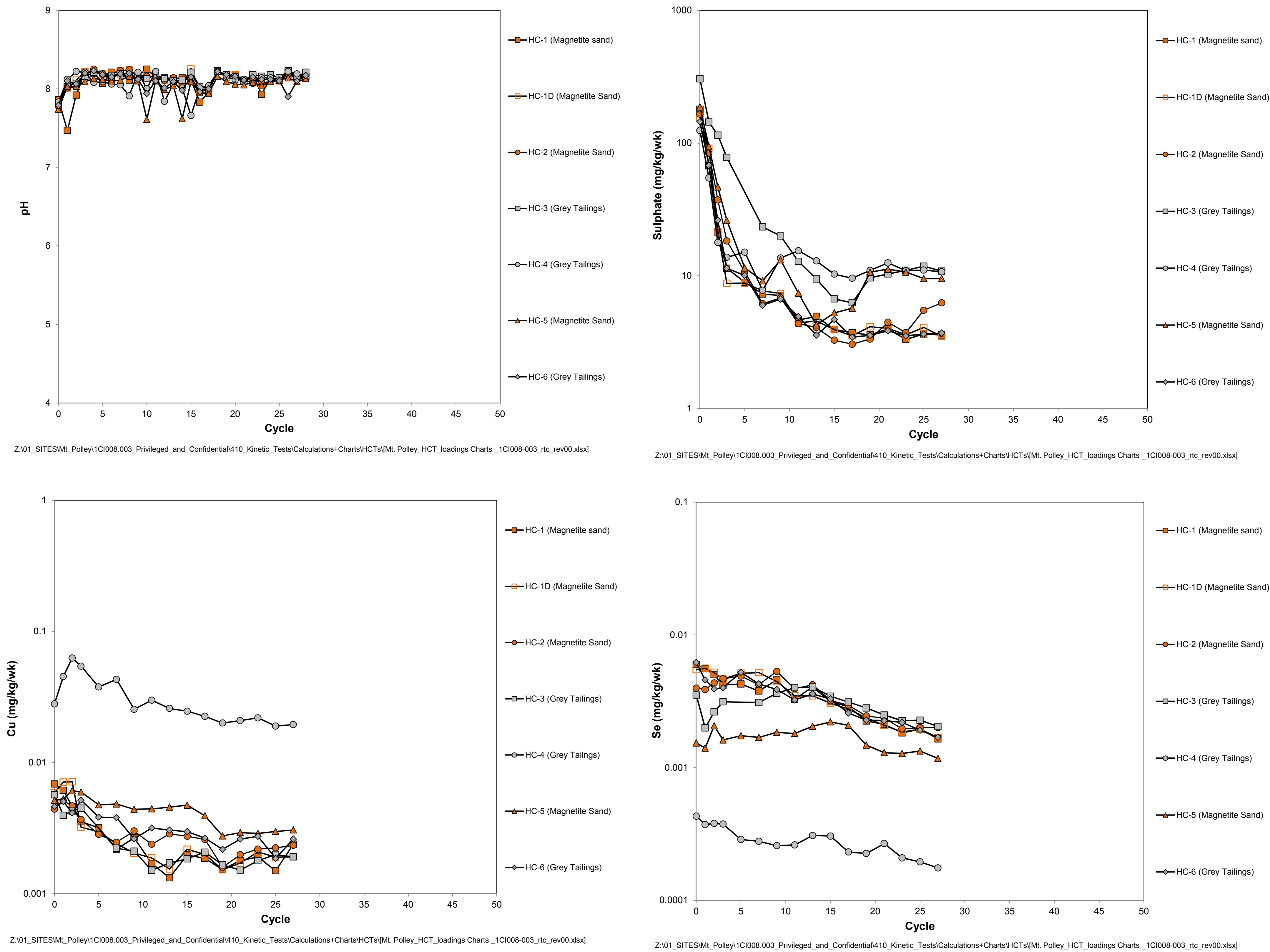

Figure 4-3: Humidity cell loadings charts for pH, sulphate, copper, and selenium.

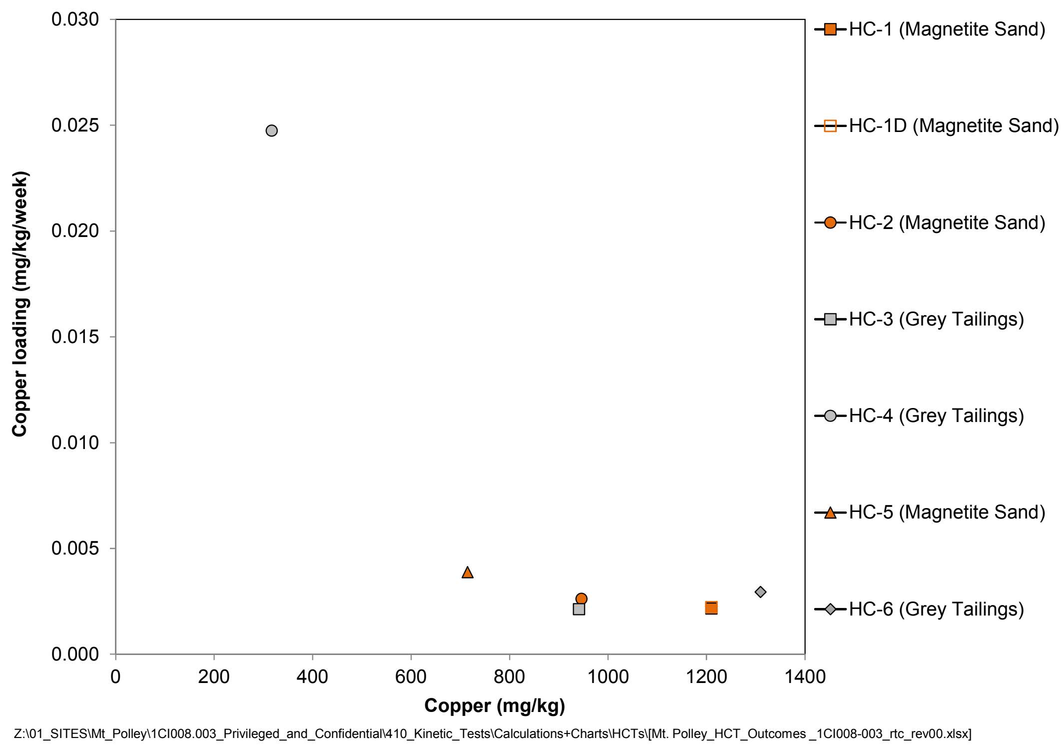

Figure 4-4: Comparison of average copper leaching rate versus solid phase copper content.

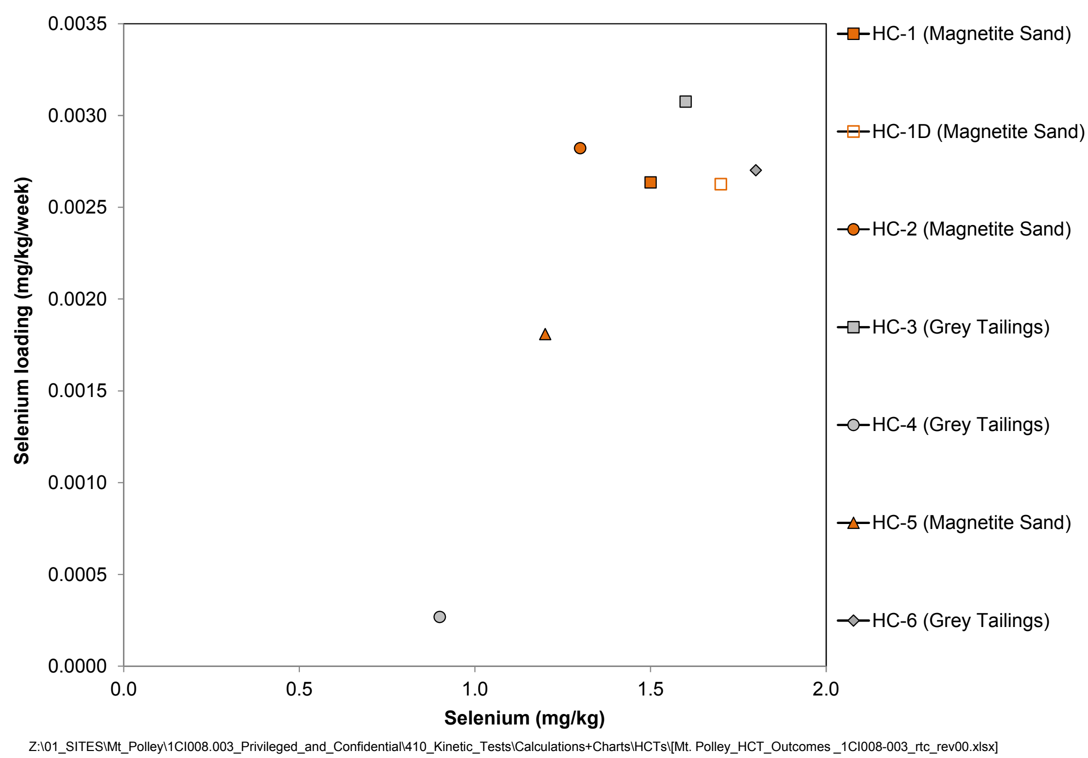

Figure 4-5: Comparison of average selenium leaching rate versus solid phase selenium content.

4.3.3 Columns

At the time of reporting, 25 weeks of data had been received for the magnetite sand samples and only 8 weeks for the grey tailings sample. Concentration charts for columns for all parameters with BC FAL guidelines are provided in Appendix E and stable loading rates are provided in Appendix D. Results for pH, sulphate, copper and selenium are provided in Figure **4-6**, for the same reason as described in Section 4.3.2.

Loading rates (i.e. mg/kg/week) are also being used to show leaching results as described in Section 4.3.2. The one difference between the columns and the humidity cells is that in the columns water initially took several weeks to travel through the materials and be collected. Column 3 (COL-3; grey tailings) still takes several weeks to collect enough leachate for analysis. As a result, the rates for columns are calculated based on how long water took to travel through the column and be collected. For the magnetite sand columns (COL-1 and COL-2), this is now the same as humidity cells (i.e. one week) but the grey tailings column divides the rate by three weeks.

Column leachates are alkaline, with pHs just slightly above 8.0 and are dominated by sulphate, alkalinity (predicted to be bicarbonate), calcium and lesser amounts of magnesium, potassium and sodium, which is similar to the humidity cells. A comparison of humidity cell and column leachates is provided in Section 4.3.4. Release rates for major cations and trace elements have generally just begun to stabilize for the magnetite sands columns (COL-1 and COL-2), but have still not stabilized in the grey tailings column (COL-3). Generally all parameters are either stable or trending down slightly. Initially, elevated sulphate release was observed for most tests in the first few weeks probably reflecting flushing of oxidation products accumulated prior to testing.

With only three samples, correlations are not particularly meaningful, but the differences in rates are consistent with solid phase content where highest sulphate, copper and selenium rates also contain highest solid phase content of these parameters.

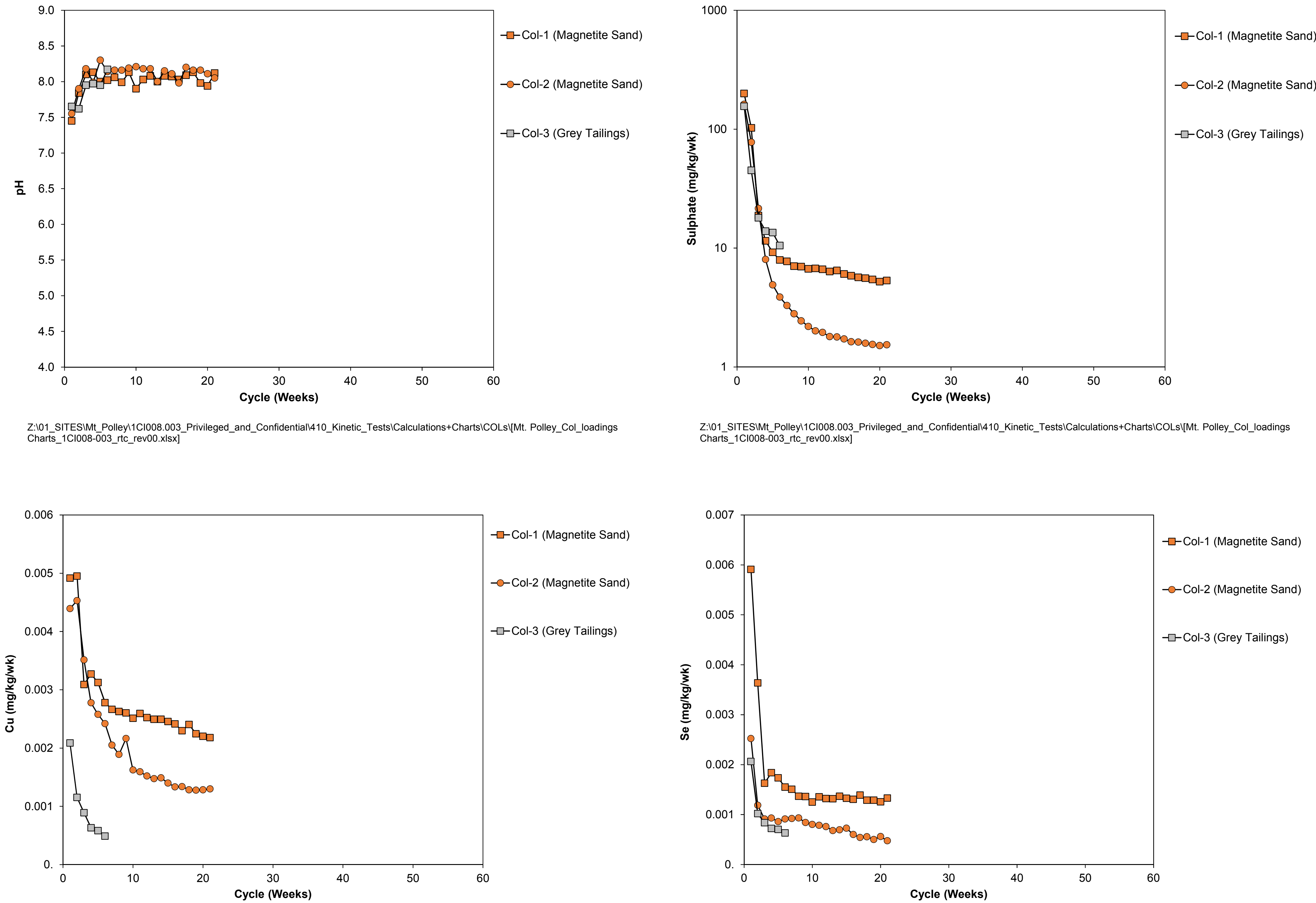

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Figure 4-6: Column cell loadings charts for pH, sulphate, copper, and selenium.

4.3.4 Kinetic Test Comparison

A comparison between humidity cells and columns for pH, sulphate, copper and selenium provides the basis to understand how the different test configurations impact leaching rates in order to better predict how tailings materials in the field might react and impact water chemistry. The comparison also included mineral saturation indices (SI) for calcite ($CaCO_3$), malachite ($Cu_2CO_3(OH)_2$) and tenorite (CuO) using the equilibrium modelling software package PHREEQC (version 2.17.4137) (Parkhurst and Appelo, 1999). A number of secondary minerals were reviewed in the calculations but the above three were chosen as they illustrate the influence of longer flow paths (calcite) and also potential controls on copper solubility (malachite and tenorite). Ferrihydrite (an iron oxyhydroxide) is also likely at saturation in the tests and is an important secondary mineral for attenuating metals, but concentrations were always below detection and therefore SI calculations were not possible. In the SI calculation, the most recent chemistry from each of the tests was used and equilibrated with the atmosphere. The comparison is provided in Table 4-3.

The pH conditions were essentially the same for both tests at around pH 8.0. Sulphate was lower in HC-1, as compared to its column pair, higher for HC-2 and essentially the same (i.e. less than 15% RPD) for HC-3. Copper release rates were essentially the same in paired sample 1, but lower in the other two paired column tests. Selenium release rates were always lower in the column tests, by approximately an order of magnitude in paired samples two and three. The columns have been running for a shorter period of time and rates are expected to continue decreasing for the columns and therefore differences will potentially become more pronounced.

Saturation indices showed that flow path was impacting mineral solubility in the magnetite sand tests. When interpreting SIs, positive values indicate that the mineral is predicted to precipitate, whereas negative numbers indicate that the mineral would not precipitate. For both of the magnetite sand tailings samples, calcite and tenorite were below saturation in the humidity cells, but above saturation in the column tests indicating that the longer flow path would likely lead to calcite and tenorite precipitation. Malachite was at or just below saturation. The grey tailings sample had nearly identical saturation indices in both the humidity cell and column test. While the flow path is about half of the distance as the magnetite sands samples, calcite was already saturated in the humidity cell test and did not need a longer flow path to reach mineral equilibrium. The grey tailings are taking nearly three times as long to allow water to pass through the column, which appears to be support mineral equilibrium to be reached over a shorter flow path. Implications of these results are discussed in Section 5.3.

Table 4-3: Comparison of humidity cell and column leaching rates and mineral equilibria.

Tailings Type	Test	Date Started	pH avg	SO_4 mg/kg/wk	Cu mg/kg/wk	Se mg/kg/wk	Saturation Indices Calcite	Malachite	Tenorite
Magnetite Sand	HC-1	March 6, 2015	8.1	4.3	0.0022	0.0026	-0.2	-1.2	-0.1
	COL-1	April 28, 2015	8.0	6.0	0.0024	0.0013	0.7	0.3	0.7
Magnetite Sand	HC-2	March 6, 2015	8.1	4.9	0.0026	0.0028	-0.3	-1.3	-0.2
	COL-2	April 30, 2015	8.1	1.7	0.0014	0.0006	0.3	-0.3	0.4
Grey Tailings	HC-3	March 6, 2015	8.1	11	0.0021	0.0031	0.3	-1.2	-0.1
	COL-3	May 20, 2015	7.9	12	0.00052	0.00067	0.3	-1.1	0.0

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5 Discussion

5.1 Overview

The overall geochemical characterization program outlined by SRK (2015) was developed to provide information on the potential for leaching from the spilled tailings. The non-sulphide copper analysis results can be broadly applied to both subaerial and subaqueous leaching, whereas the kinetic tests are specifically for subaerial weathering of the spilled tailings along Hazeltine Creek. Both of these are discussed further below.

Previous interpretations by SRK (2015) indicated that the risk of ARD in the spilled tailings was low. The kinetic tests continue to support that ARD is a low risk and contact water from the Hazeltine Creek tailings will be under neutral pH conditions. As a result, the focus of the discussion below is on neutral metal leaching.

5.2 Non-sulphide Copper

The tailings at Mount Polley are expected to be depleted in sulphide minerals relative to ore due to metal recovery during ore processing (i.e. sulphide flotation) and as a result, the non-sulphide fraction is expected to be enriched in the tailings compared to typical ore. This was confirmed in the spilled tailings collected in this study, with non-sulphide copper representing up to 66% of the total copper present, with the remaining copper (44%) associated with the sulphide fraction. This is also consistent with previous findings reported by SRK (2015).

The mineral form of this non-sulphide copper is likely the silicate chlorite (a common rock-forming, iron magnesium aluminum silicate mineral) based on previous mineralogical characterization work (SRK 2015). In terms of environmental significance, previous work (Taplin 2002; Henry 2009) and this study have shown that the non-sulphide fraction is relatively insoluble and copper leaching from this fraction can be considered a low leaching risk regardless of whether it is in a subaerial or subaqueous environment.

The non-sulphide fraction also contained a small portion of selenium, with an average of 14% and a maximum value of 23% calculated. While this may lower leaching rates expected if selenium was only associated with the sulphide fraction, the tailings would still contain over 1 mg/kg of 'reactive' selenium and be considered enriched when compared to typical crustal averages.

5.3 Tailings Weathering Rates

Weathering rates for subaerial tailings situated along Hazeltine Creek are being established, with testing now past half way of the recommended 40 weeks. As sample selection included materials that represented median and upper 95th percentile materials in terms of sulphur, copper and selenium concentration, leaching variability is also being established.

Any future use of laboratory leaching rates for predicting contact water chemistry (i.e. geochemical source terms) will need to consider a number of factors such as the surface area of the tailings, site temperature and the length of the water flow path through the tailings (Day et al, 2014). Particle size and water contact factors do not need to be considered as for tailings specifically, testing is performed on as-received materials and water contact is also expected to be much higher than more coarse grained material such as waste rock. For water chemistry predictions that involve coarse waste rock, differences in water contact can be significant.

The influence of flow path on the test materials can already be seen in the preliminary results presented in this report. The longer flow paths in the columns containing magnetite sands samples resulted in calcite saturation, as well as tenorite and increases in malachite saturation, whereas these minerals were not saturated in the humidity cell tests (Table 4-3). As discussed in SRK (2015), the presence of secondary copper minerals will tend to keep the concentration of copper at a ‘ceiling’ concentration, which is supported by measured concentrations at other copper porphyry sites at neutral pH (Day and Rees, 2006). For locations along Hazeltine Creek where the tailings settled in thin layers (i.e. less than 0.5 metres), dilution from precipitation is expected to be high and concentrations could be even lower than predicted by mineral solubility limits.

Selenium is not expected to be influenced by a mineral solubility control at neutral pH and fully oxygenated conditions, but there was a difference in leaching rates between the columns and humidity cells that was not observed with the sulphate leaching rates. Sulphate in the humidity cells and columns is considered a conservative tracer as concentrations are not high enough for mineral precipitation of sulphate minerals that could have a significant control on concentrations (i.e. precipitation of gypsum) and extremely low redox conditions are needed to reduce sulphate to sulphide. Selenium does not need to have very low reducing conditions to transition from its oxidized form selenate to selenite or even elemental selenium (MEND 2015). More reduced forms of selenium will be preferentially removed from solution as selenite has a much higher sorption affinity for mineral surfaces than selenate and elemental selenium will precipitate. As a result, the difference observed for selenium leaching rates between the humidity cells and columns may be a function of redox differences. Continued monitoring of the tests will help confirm this interpretation.

6 Conclusions

The results and interpretations presented in this report are a continuation of the geochemical characterization studies undertaken on representative samples of tailings that spilled into Hazeltine Creek in August 2014 from the MPM dam failure. The continued studies have included non-sulphide copper association, humidity cells and column testing.

The results indicate that a significant amount of copper (up to 66%) is associated with the non-sulphide portion (likely chlorite) of the tailings and is considered to be non-reactive. This is based on previous studies and the results provided in this report that required acidic conditions to leach copper associated with the non-sulphide fraction.

Kinetic testing confirmed that leaching considerations are under neutral to alkaline conditions and continue to support the previous assessment that ARD is not expected in these materials. Based on 32 weeks of testing, leaching rates are beginning to stabilize and general downward trends are expected to continue as the testing progresses. Variability in leaching rates is also being established and water contact chemistry predictions (i.e. geochemical source terms) should be possible after 40 weeks of testing.

For any tailings materials with water flow paths longer than half a metre, mineral solubility controls for copper are expected. Longer flow paths in the fine grained materials may also be conducive to lower rates of oxygen diffusion and therefore conditions that support selenium reduction to its more insoluble forms such as selenite and elemental selenium.

Testing is on-going and the current assessment of tailings reactivity and leaching rates will be updated once testing passes 40 weeks.

This report, Mount Polley Mine Tailings Dam Failure: Update on Geochemical Characterization of Spilled Tailings, was prepared by

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Corporate Consultant (Geochemistry)

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Appendix A – Non-Sulphide Copper Analysis Results

Sample ID	Al mg/kg	As mg/kg	B mg/kg	Cd mg/kg	Co mg/kg	Cu mg/kg	Fe mg/kg	Pb mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Se mg/kg	Ag mg/kg	Zn mg/kg
Reporting Limits	0.3	0.01	1	0.001	0.01	0.05	1.0	0.005	0.005	0.005	0.05	0.01	0.001	0.3
MB1	<0.3	<0.01	<1	<0.001	<0.01	<0.05	<1	0.016	0.0056	<0.005	<0.05	<0.01	<0.001	<0.3
L1518225-4	2000	4.9	1.5	0.081	1.2	520	1100	1.7	100	0.96	0.78	0.26	0.0075	6.9
L1518225-8	1900	3.4	<1	0.073	1.5	170	1700	0.72	170	0.089	1.4	0.037	<0.001	4.8
L1518225-37	1500	2.9	<1	0.063	1.1	290	1100	1.1	88	0.25	1.1	0.092	0.0029	4.1
L1518225-44	1000	2.3	1.0	0.072	1.4	100	1300	0.77	150	0.038	1.7	0.035	<0.001	5.8
L1518225-60	1300	5.0	<1	0.069	1.2	740	1200	1.3	110	0.68	0.6	0.23	0.0063	3.2
L1518225-72	1500	3.8	<1	0.094	0.81	390	1000	1.3	78	0.58	0.52	0.21	0.0029	6.4
L1518225-72DUP	1400	3.9	<1	0.10	0.86	450	1000	1.4	95	0.7	0.53	0.18	0.0048	7.7
L1518225-74	1900	4.3	1.1	0.072	0.85	440	1000	1.2	78	0.48	0.59	0.21	0.0042	5.2
L1519001-3	2200	3.9	<1	0.081	1.4	320	1300	1.1	120	0.25	1.4	0.12	0.0028	5.0
L1519001-9	1700	5.4	<1	0.09	0.97	450	1500	1.7	110	0.45	0.84	0.22	0.0034	5.3
L1519001-26	2300	4.9	1.4	0.083	1.3	480	1300	1.8	110	0.54	0.85	0.24	0.0054	6.2
L1519001-35	2300	5.3	1.4	0.086	1.4	510	1300	1.6	120	0.56	0.81	0.28	0.0076	7.1
L1519001-38	1200	4.0	<1	0.072	0.69	400	1100	1.2	72	0.51	0.64	0.18	0.0028	4.1
L1519001-39	1300	4.2	<1	0.08	0.77	440	1200	1.3	80	0.57	0.61	0.2	0.0024	4.6
L1519001-40	2700	6.2	1.9	0.10	1.6	590	1600	1.9	130	0.84	0.98	0.3	0.0062	8.0
L1520490-2	2200	4.5	<1	0.045	0.42	370	520	0.77	39	0.43	0.48	0.23	0.002	2.2
L1520490-5	2400	5.0	1.3	0.078	1.3	430	1300	1.2	110	0.26	0.83	0.23	0.0034	5.3
Quality Assurance and Quality Control														
Duplicate Pair: L1518225-72 & L1518225-72DUP														
RPD	7%	-4%	-	-8%	-6%	-10%	1%	-8%	-20%	-20%	-1%	16%	-50%	-20%
Duplicate Pair: L1519001-38 & L1519001-39														
RPD	-5%	-6%	-	-10%	-10%	-9%	-8%	-10%	-10%	-10%	5%	-9%	14%	-10%

Note: results have been rounded to two significant figures.

Appendix B -- Geochemical Properties of Tailings

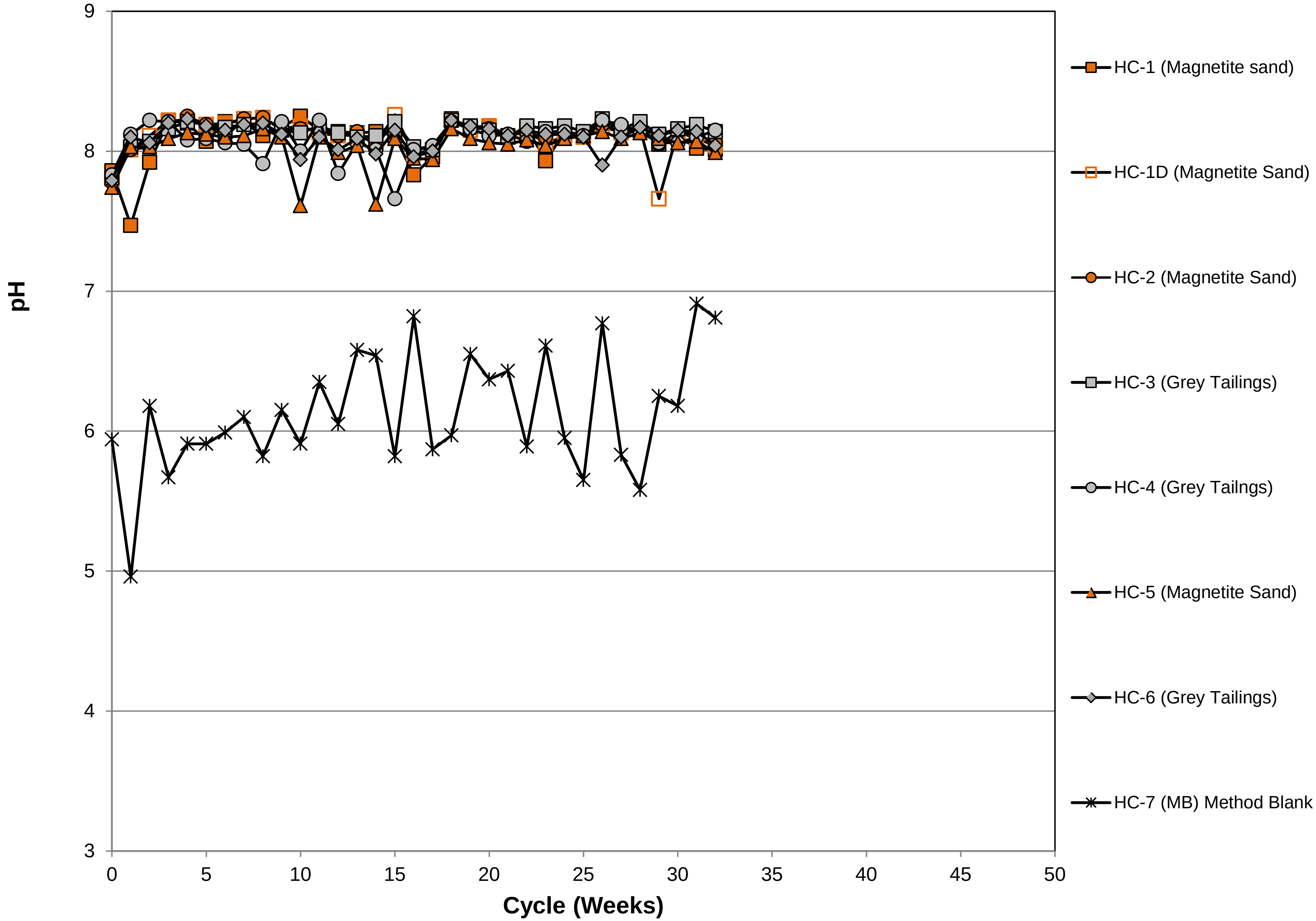
Composition

Kinetic Test	Tailings Type	Leco S %	Aqua Regia S %	Al %	As mg/kg	B mg/kg	Cd mg/kg	Co mg/kg	Cu mg/kg	Fe %	Hg mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Pb mg/kg	Se mg/kg	Ag mg/kg	Zn mg/kg
HC-1/COL-1	Magnetite Sand	0.26	0.27	1.2	13	<10	0.22	19	1200	8.0	0.14	630	5.6	9.2	6.8	1.5	0.51	82
HC-1D	Magnetitie Sand	0.27	0.27	1.2	14	<10	0.17	19	1200	8.2	0.13	610	5.1	9.0	5.5	1.7	0.60	63
HC-2/COL-2	Magnetite Sand	0.16	0.15	1.3	11	<10	0.15	16	950	5.7	0.1	520	4.3	7.1	4.6	1.3	0.33	54
HC-3/COL-3	Grey Tailings	0.16	0.15	1.8	13	<10	0.13	21	940	5.0	0.08	710	4.7	10	5.6	1.6	0.33	70
HC-4	Grey Tailings	0.17	0.09	1.3	9.6	10	0.16	12	320	4.2	0.08	600	1.8	16	5.4	0.9	0.18	55
HC-5	Magnetite Sand	0.18	0.13	1.4	10	10	0.16	12	720	4.3	0.1	560	3.6	13	9.0	1.2	0.34	53
HC-6	Grey Tailings	0.21	0.23	1.4	11	10	0.24	15	1300	4.9	0.11	620	5.1	8.2	6.0	1.8	0.53	59

Mineralogy

		Sulphides			Carbonates			Silicates											Oxides and Other			
		Pyrite	Chalcopyrite	Bornite	Calcite	Dolomite	Malachite	Quartz	Plagioclase	K-Feldspar	Sericite/Muscovite	Biotite	Clinopyroxene	Epidote Group	Garnet	Chlorite	Clays	Other Silicates	Fe-Oxides	Ti (Fe) Oxides	Apatite	Other
Kinetic Test	Tailings Type	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
HC-1/COL-1	Magnetite Sand	0.24	0.24	0.035	2.2	0.11	0.0081	3.8	24	43	1.5	1.7	4.3	0.87	2.2	3.8	1.8	1.9	7	0.29	0.7	0.027
HC-1D	Magnetitie Sand	0.32	0.24	0.02	2.5	0.051	0.013	5	25	41	1.4	1.4	5.9	0.49	2.5	3.7	1.7	2	6.5	0.23	0.6	0.051
HC-2/COL-2	Magnetite Sand	0.19	0.18	0.019	2.3	0.037	0.00048	1.3	29	43	1.1	2.2	5.1	0.47	1.8	3.6	1.9	1.9	5.3	0.24	0.68	0.027
HC-3/COL-3	Grey Tailings	0.33	0.024	0.0	2.6	0.018	0.0	1.1	27	39	1.5	3.2	5	0.28	1.3	6.9	2.3	3.1	4.9	0.11	0.88	0.054
HC-4	Grey Tailings	0.08	0.021	0.00029	0.72	0.43	0.0	27	19	24	1.7	1.2	3.9	1.1	3.4	5.2	5.3	2.9	2.8	0.64	0.44	0.036
HC-5	Magnetite Sand	0.16	0.16	0.015	1.3	0.15	0.0028	21	21	31	1.1	1.3	3.9	0.89	2.5	4.1	4.3	1.9	3.8	0.73	0.51	0.032
HC-6	Grey Tailings	0.40	0.23	0.016	4.5	0.048	0.013	3	27	39	1.8	1.6	4.6	0.4	1.8	3.8	2.8	2.2	4.9	0.28	0.81	0.021

Appendix C – Humidity Cell Concentrations Charts



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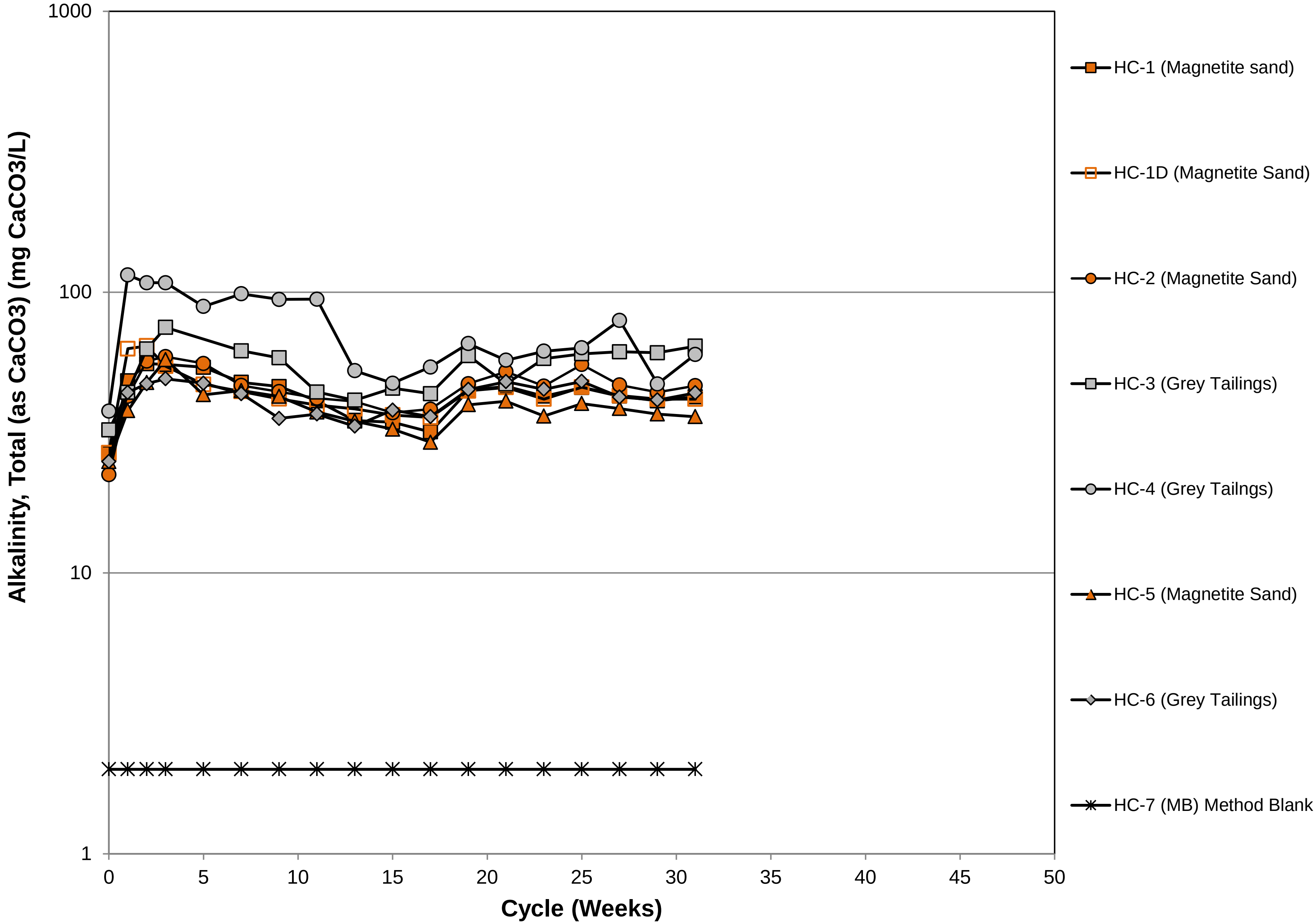

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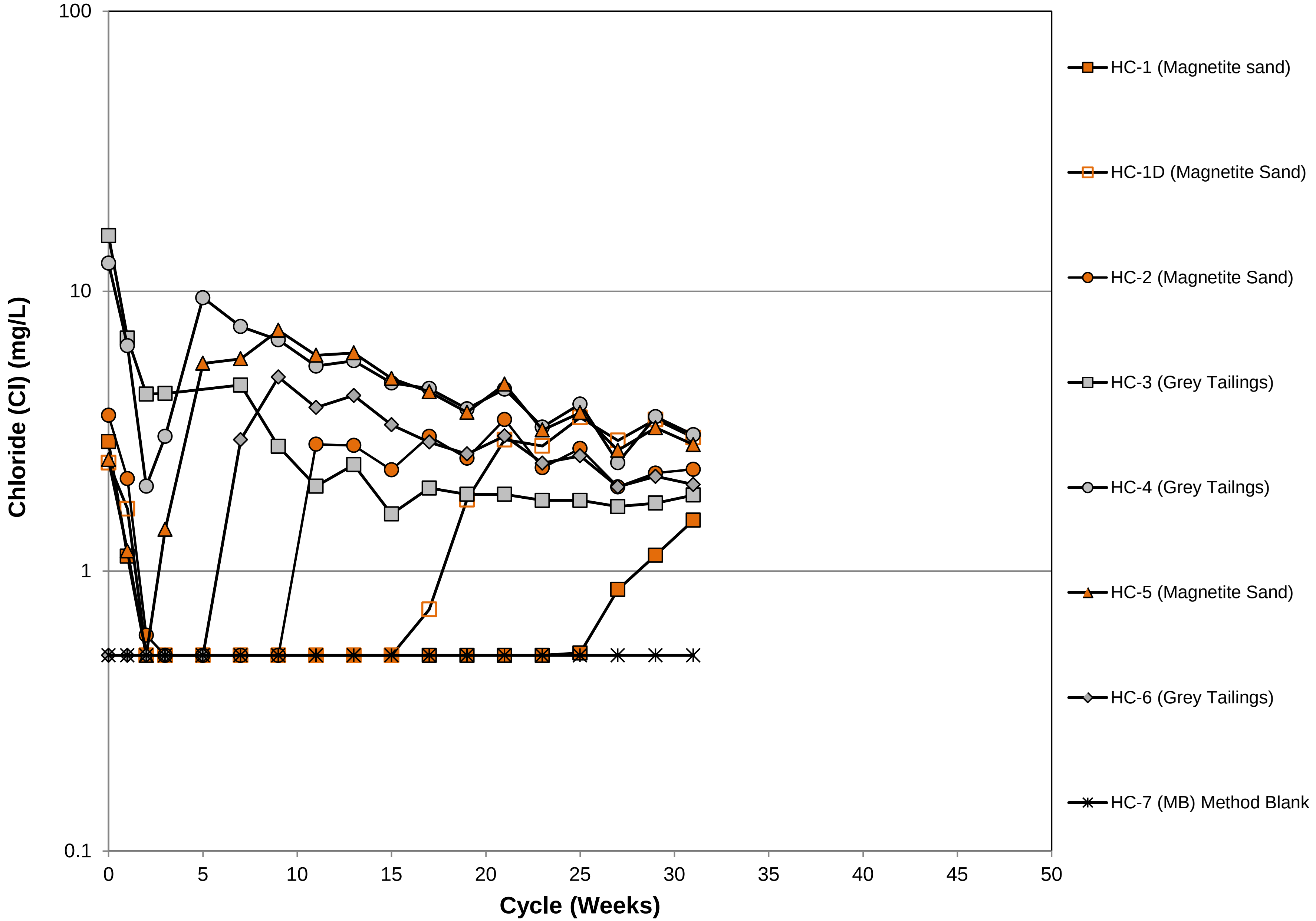

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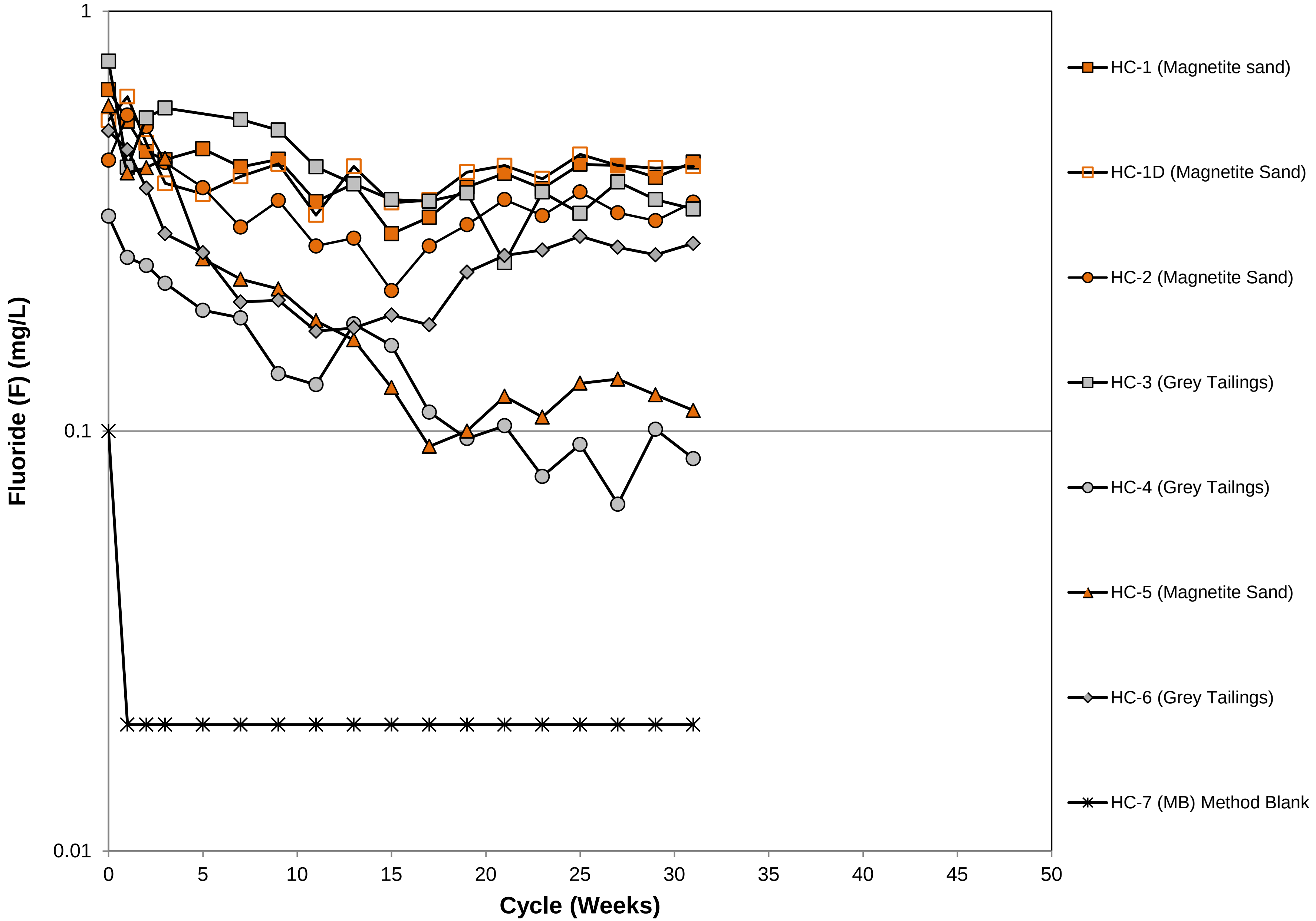

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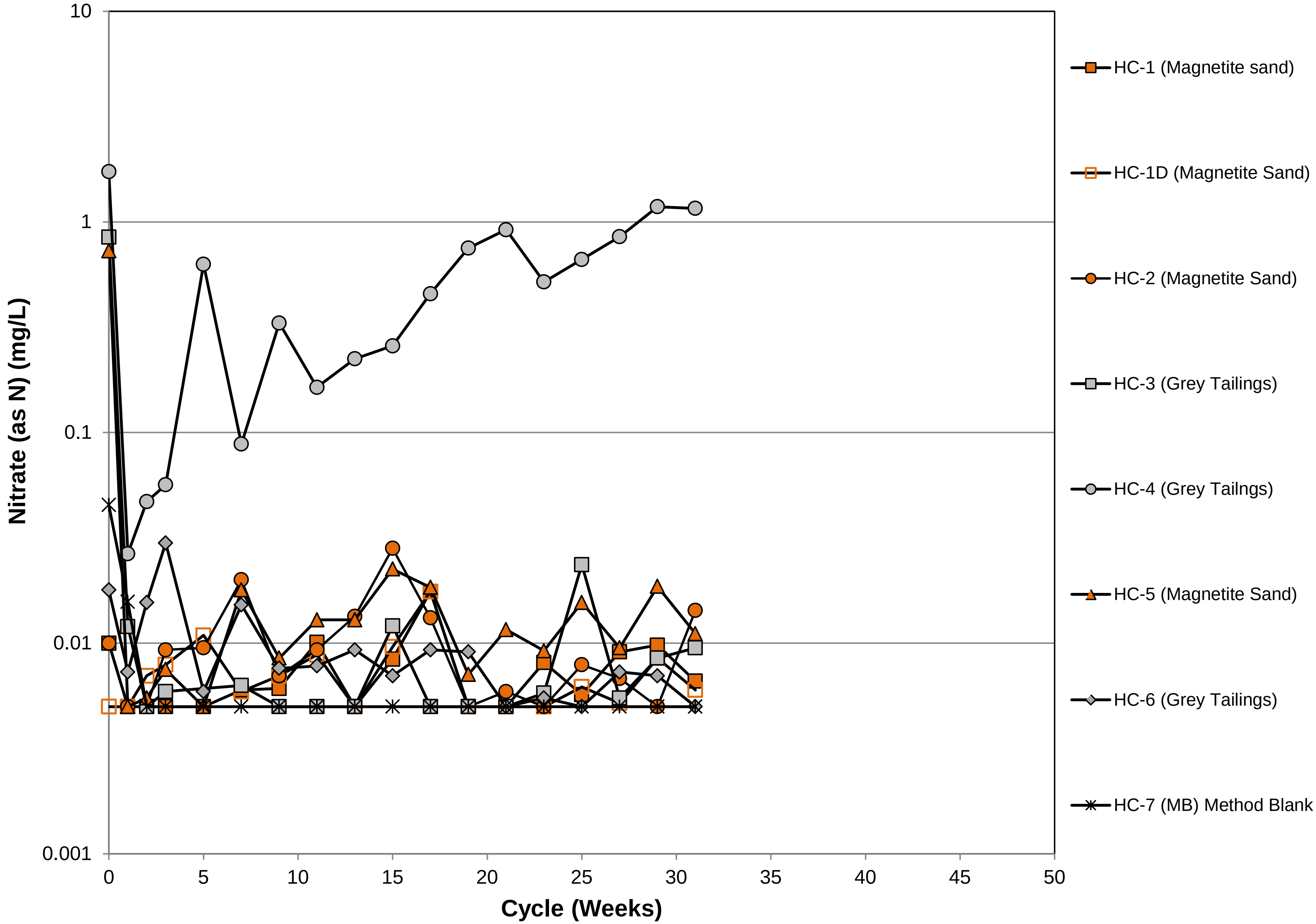

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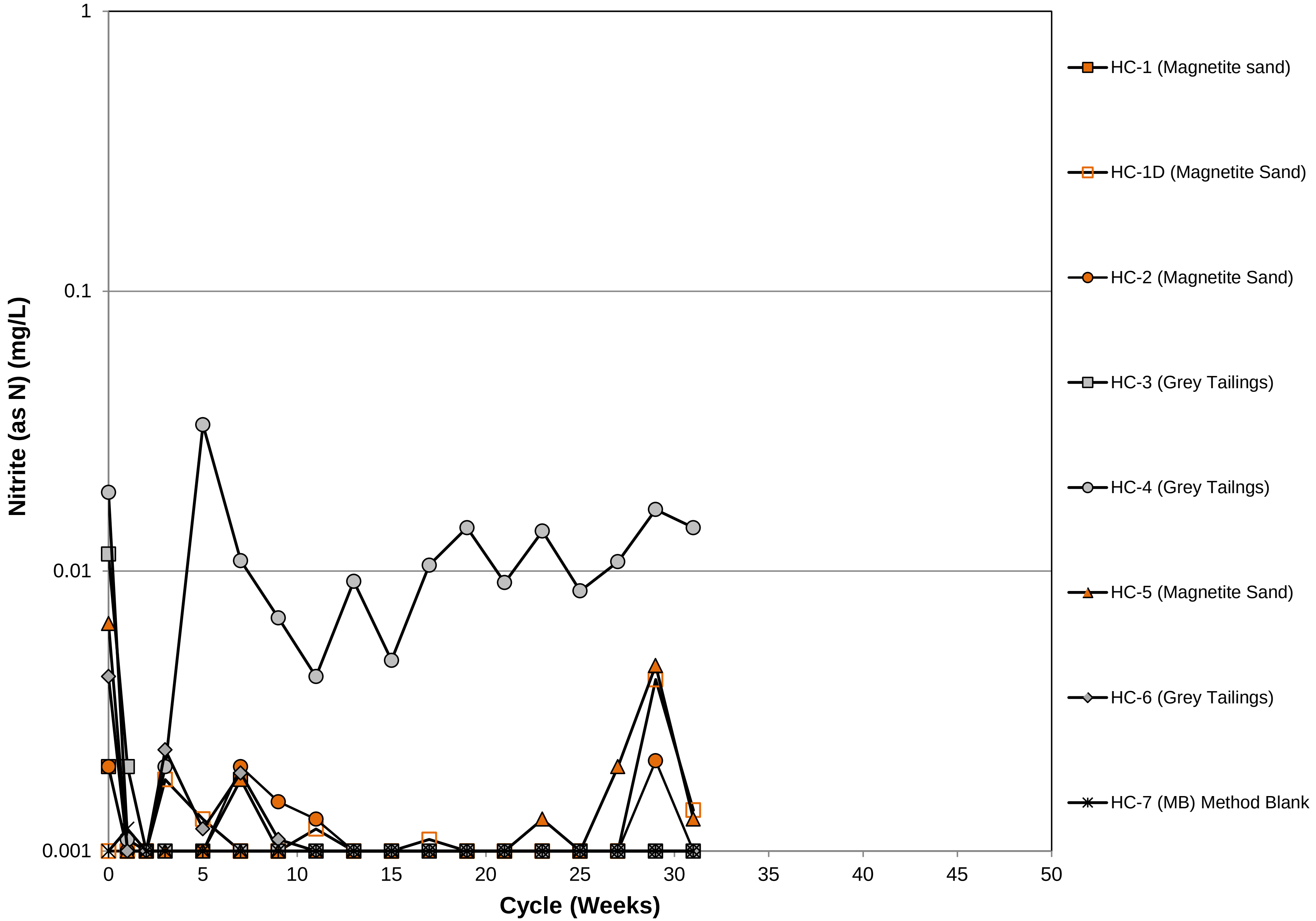

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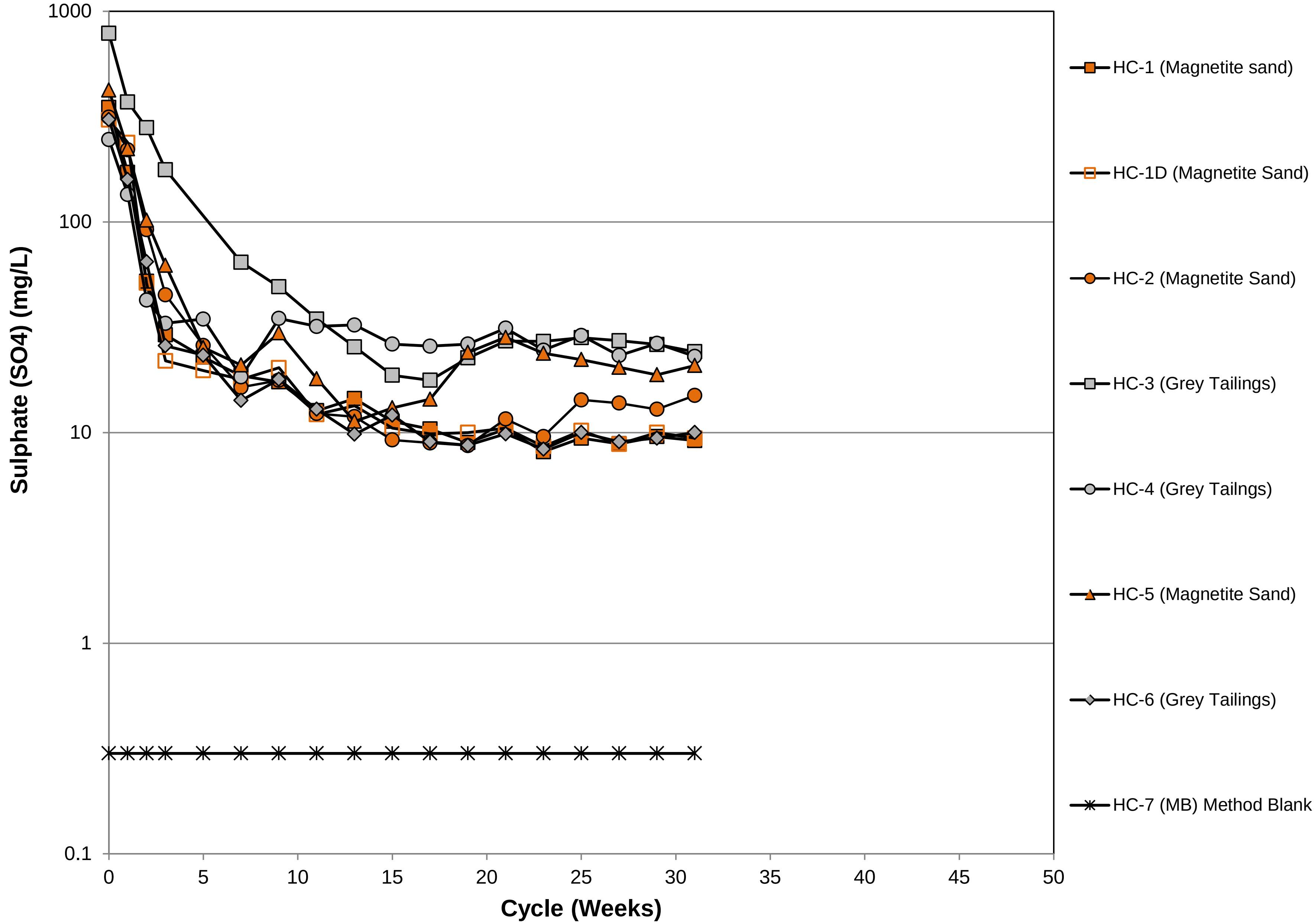

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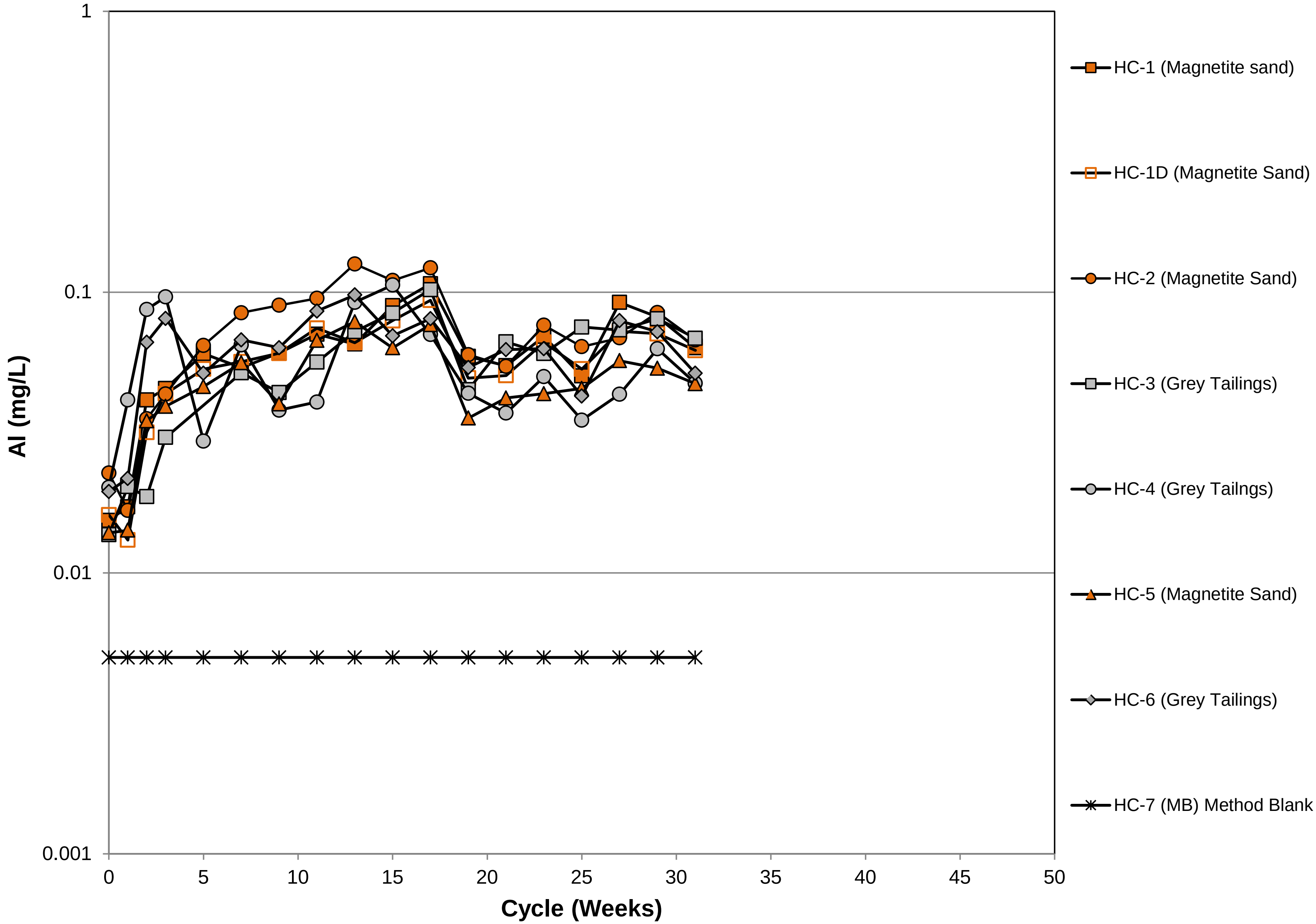

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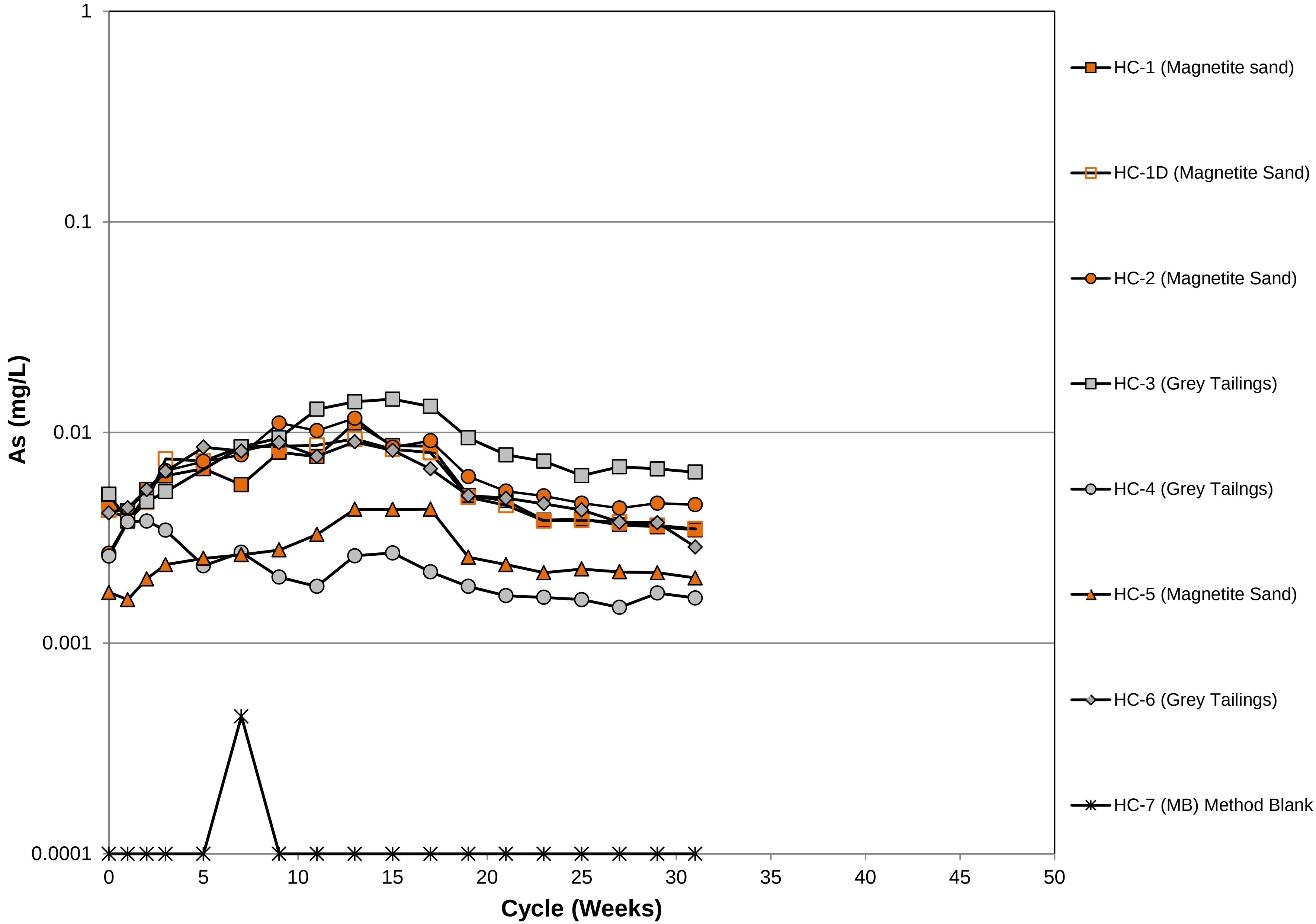

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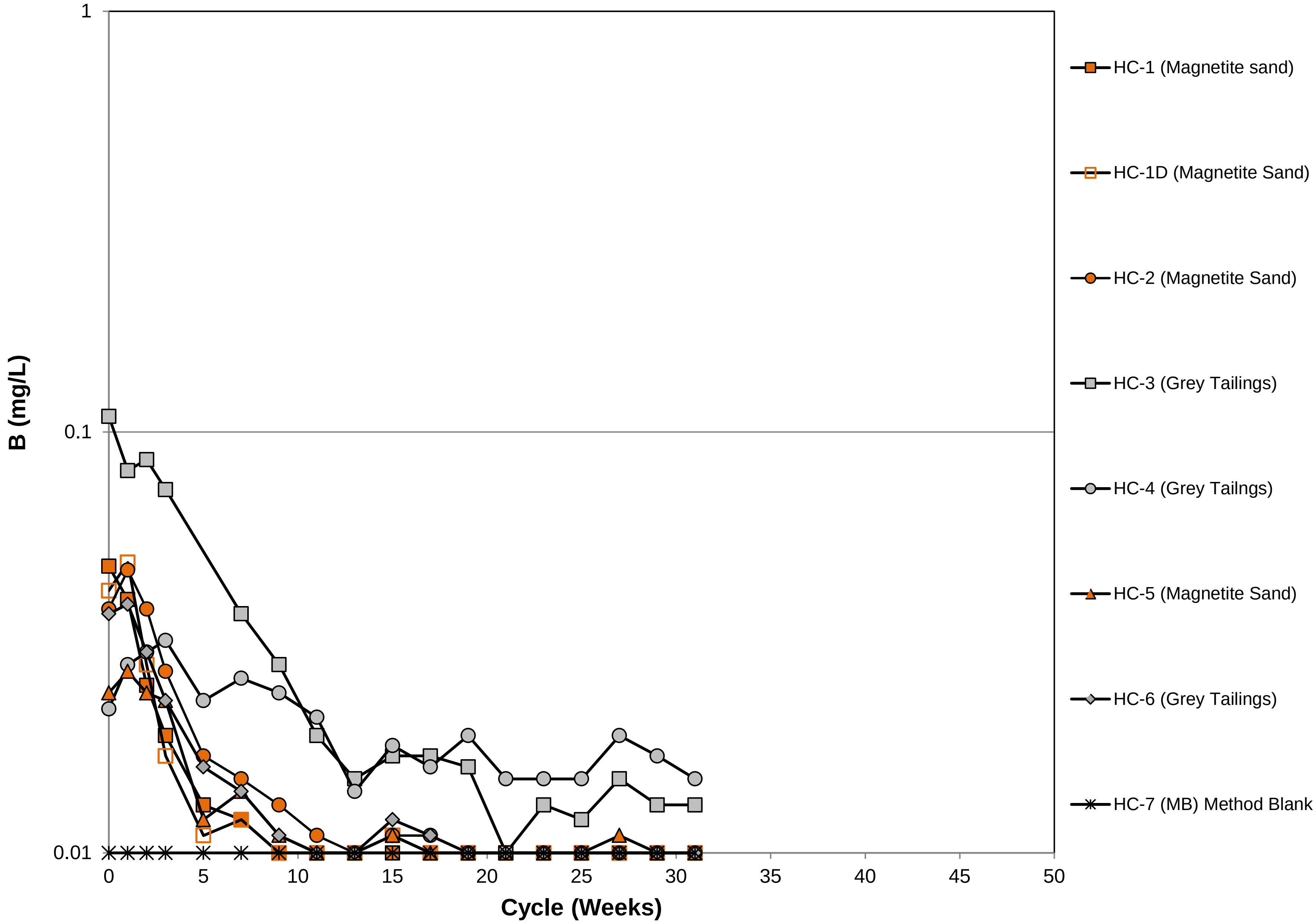

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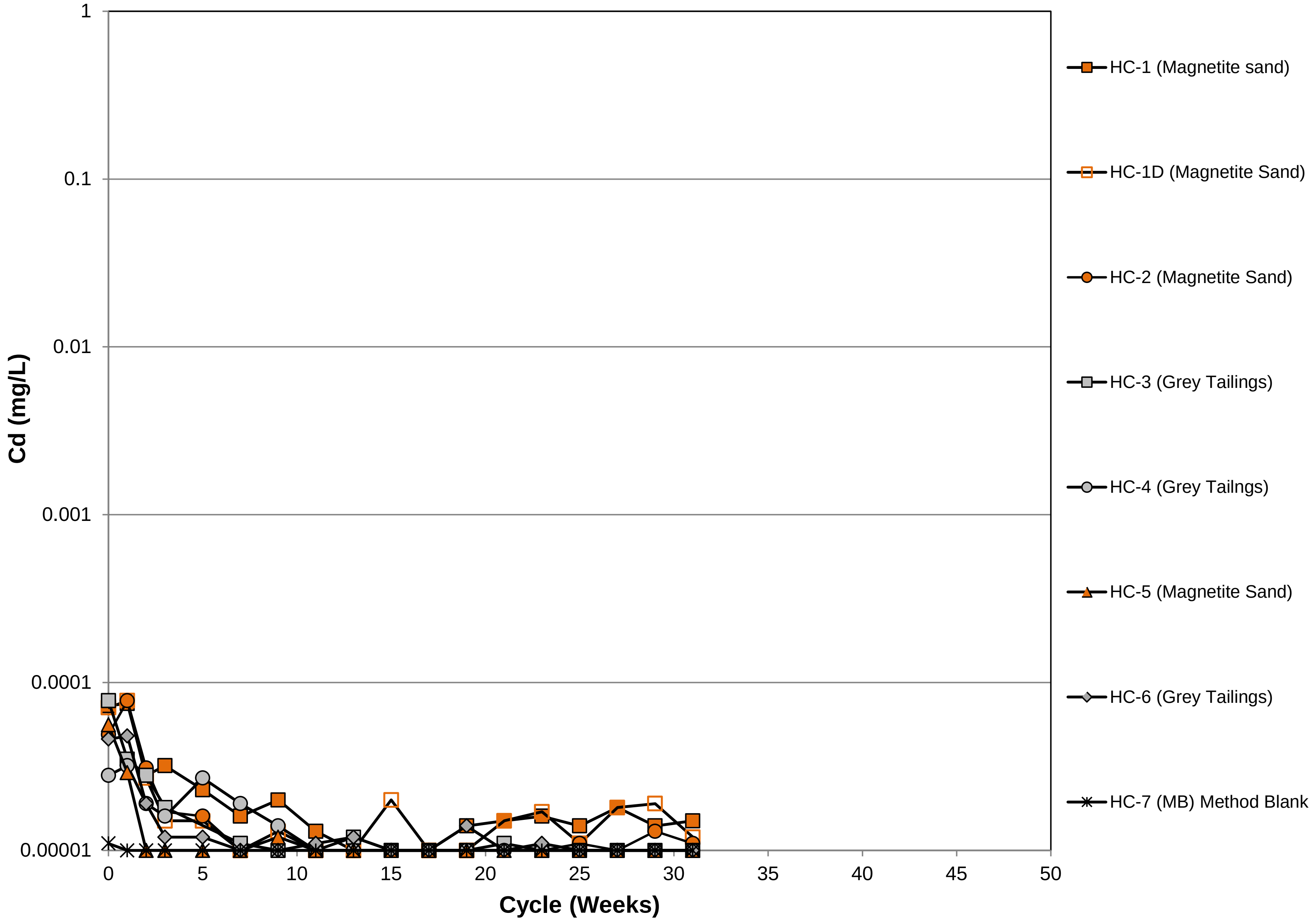

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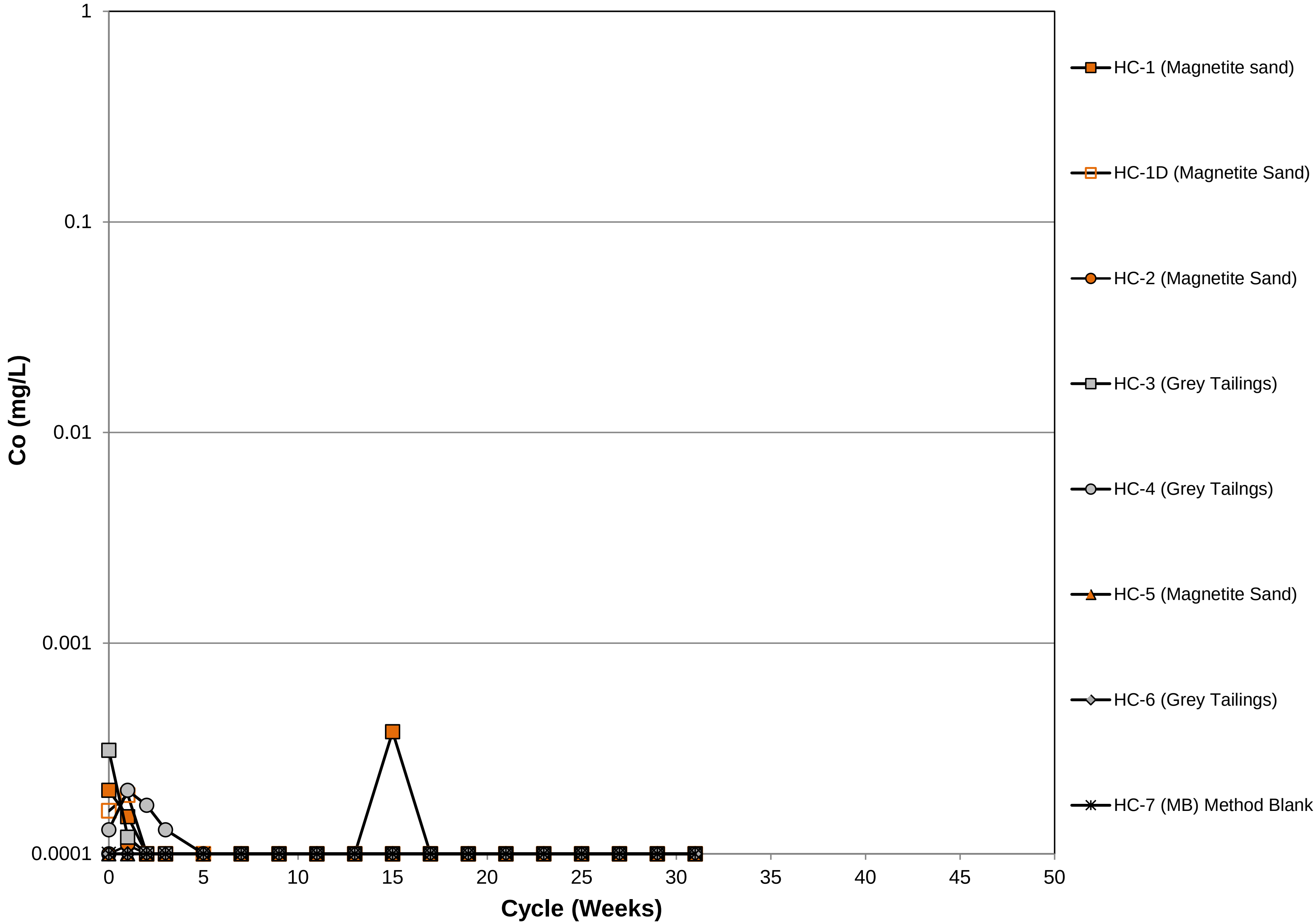

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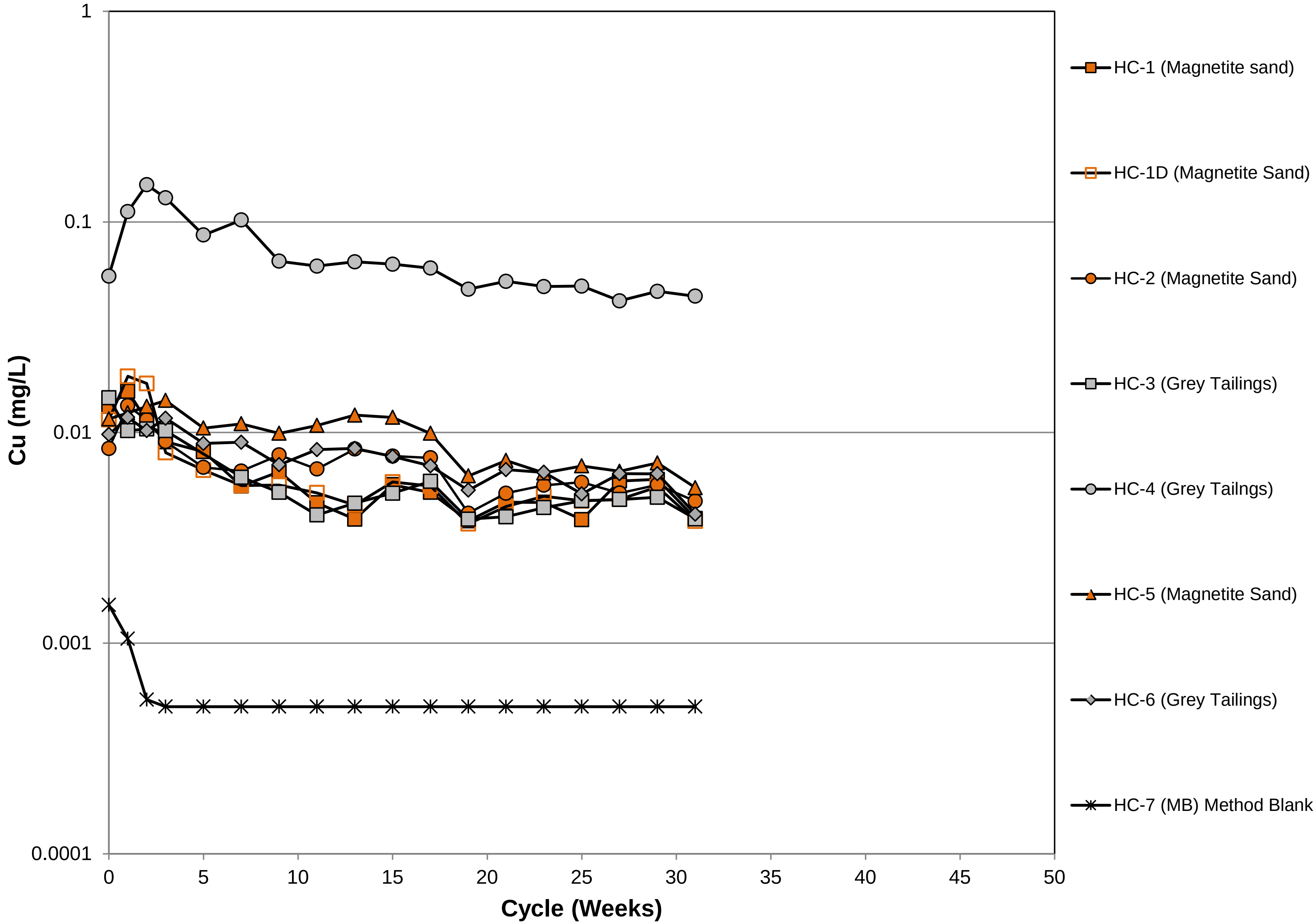

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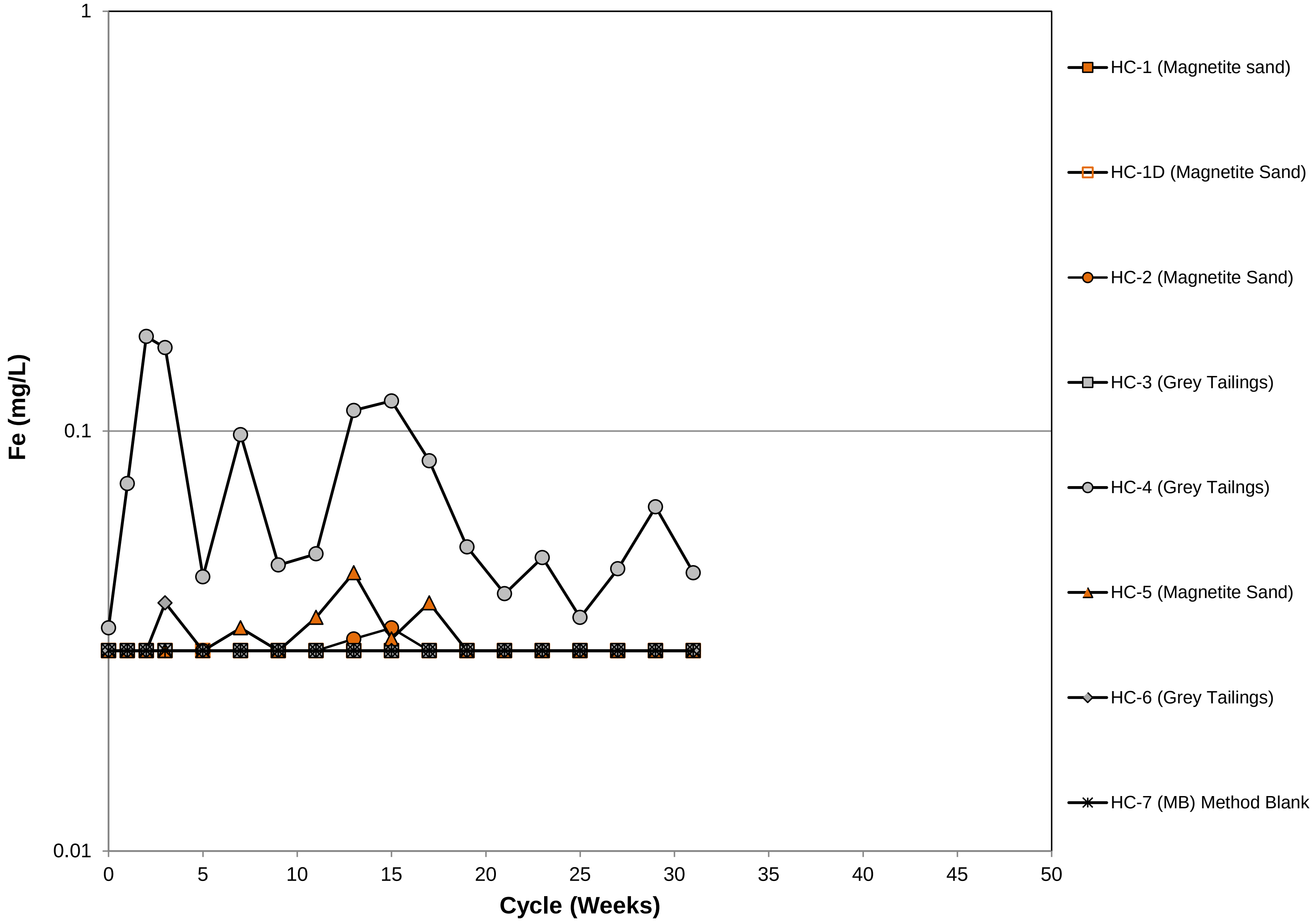

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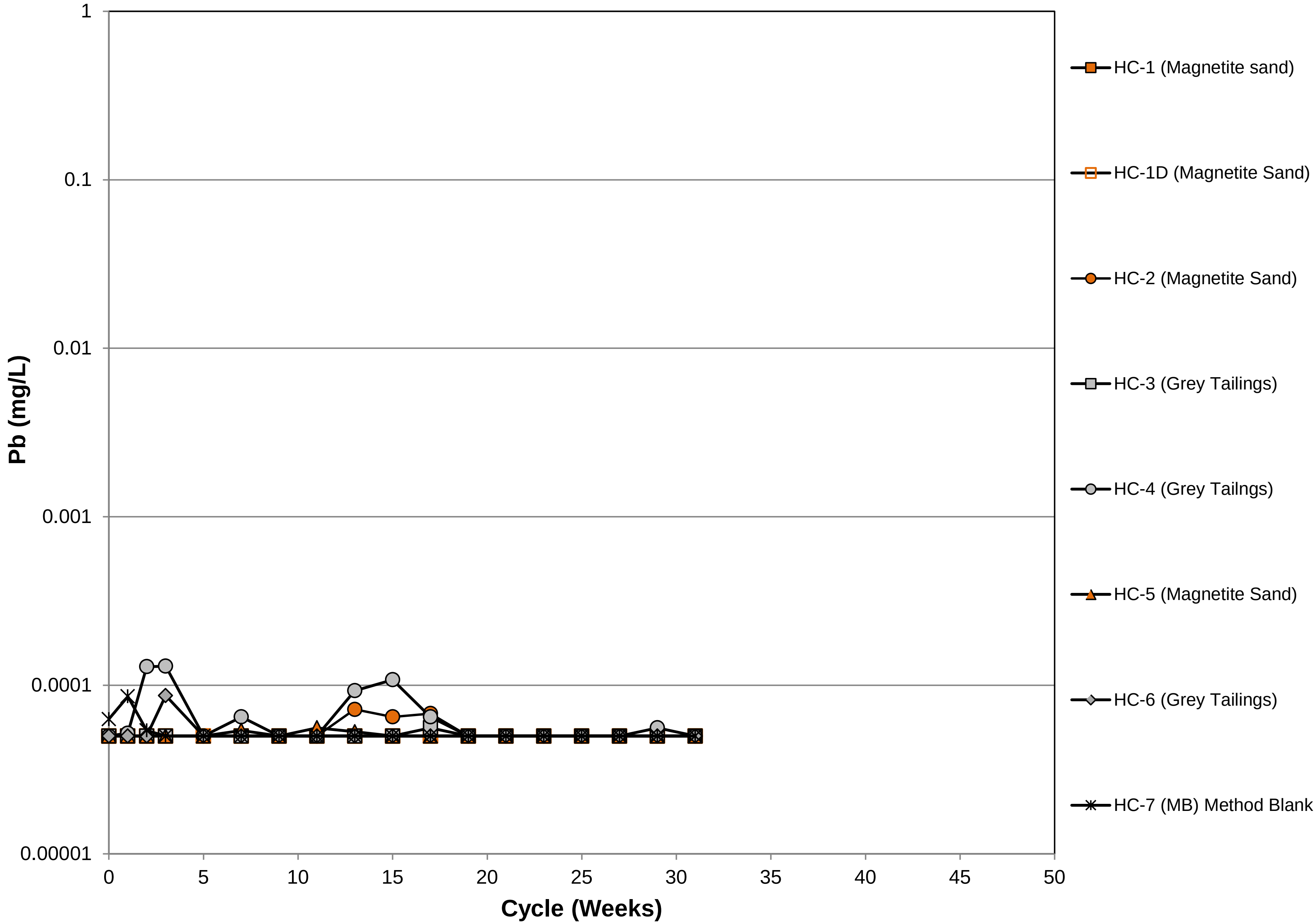
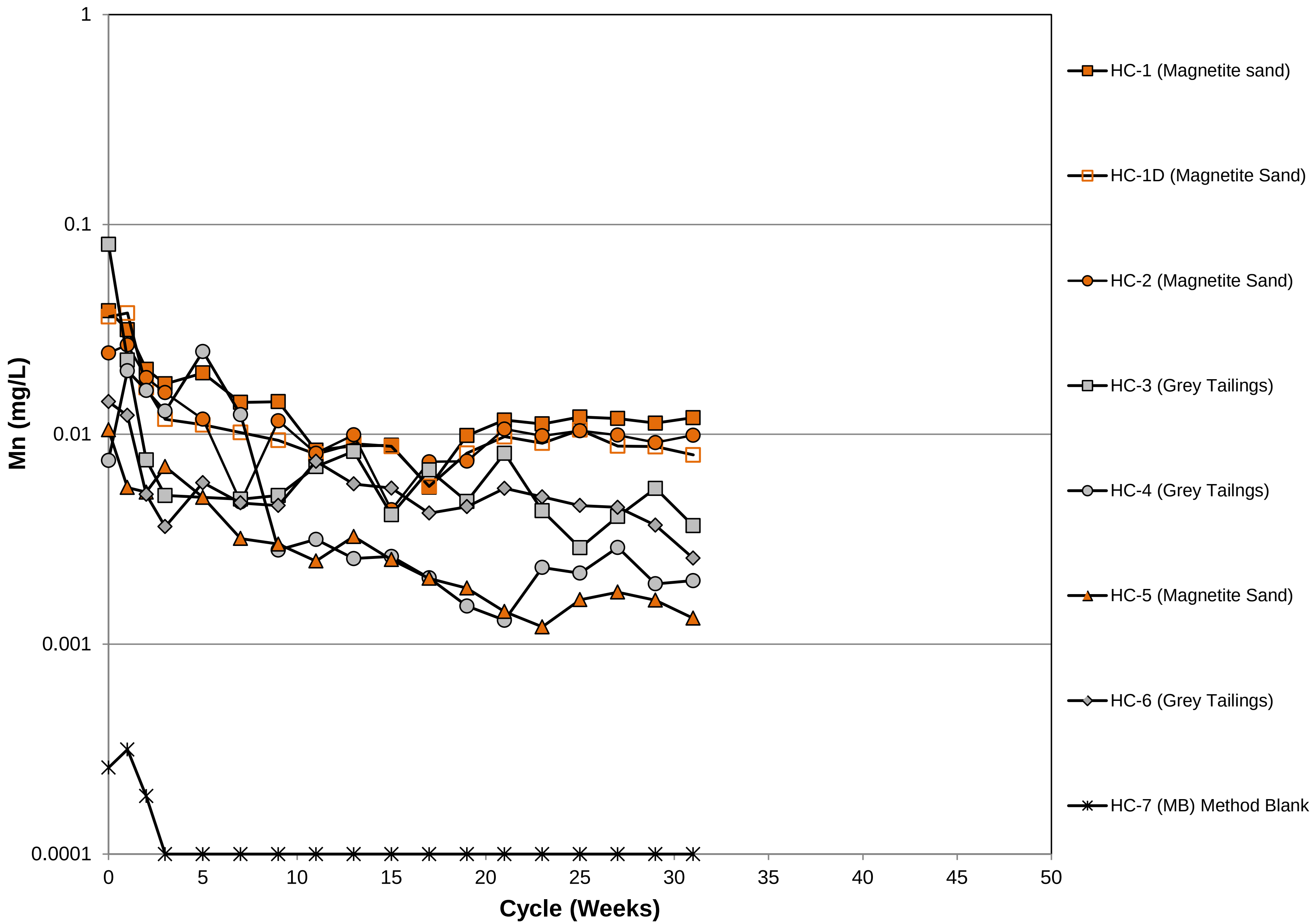


Pb (mg/L)
1
0.1
0.01
0.001
0.0001
0.00001
0
5
10
15
20
25
30
35
40
45
50
Cycle (Weeks)
HC-1 (Magnetite sand)
HC-1D (Magnetite Sand)
HC-2 (Magnetite Sand)
HC-3 (Grey Tailings)
HC-4 (Grey Tailngs)
HC-5 (Magnetite Sand)
HC-6 (Grey Tailings)
HC-7 (MB) Method Blank



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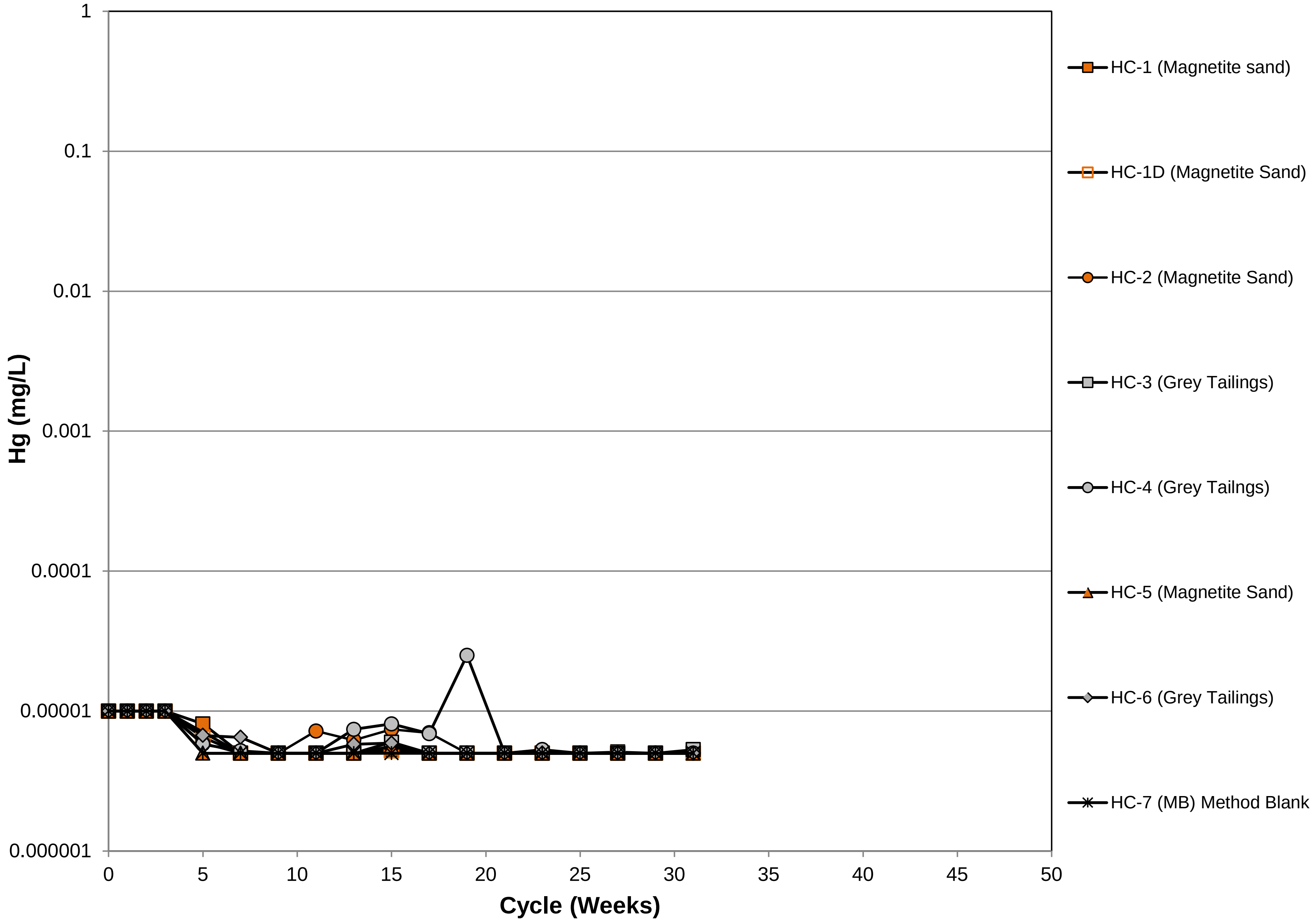

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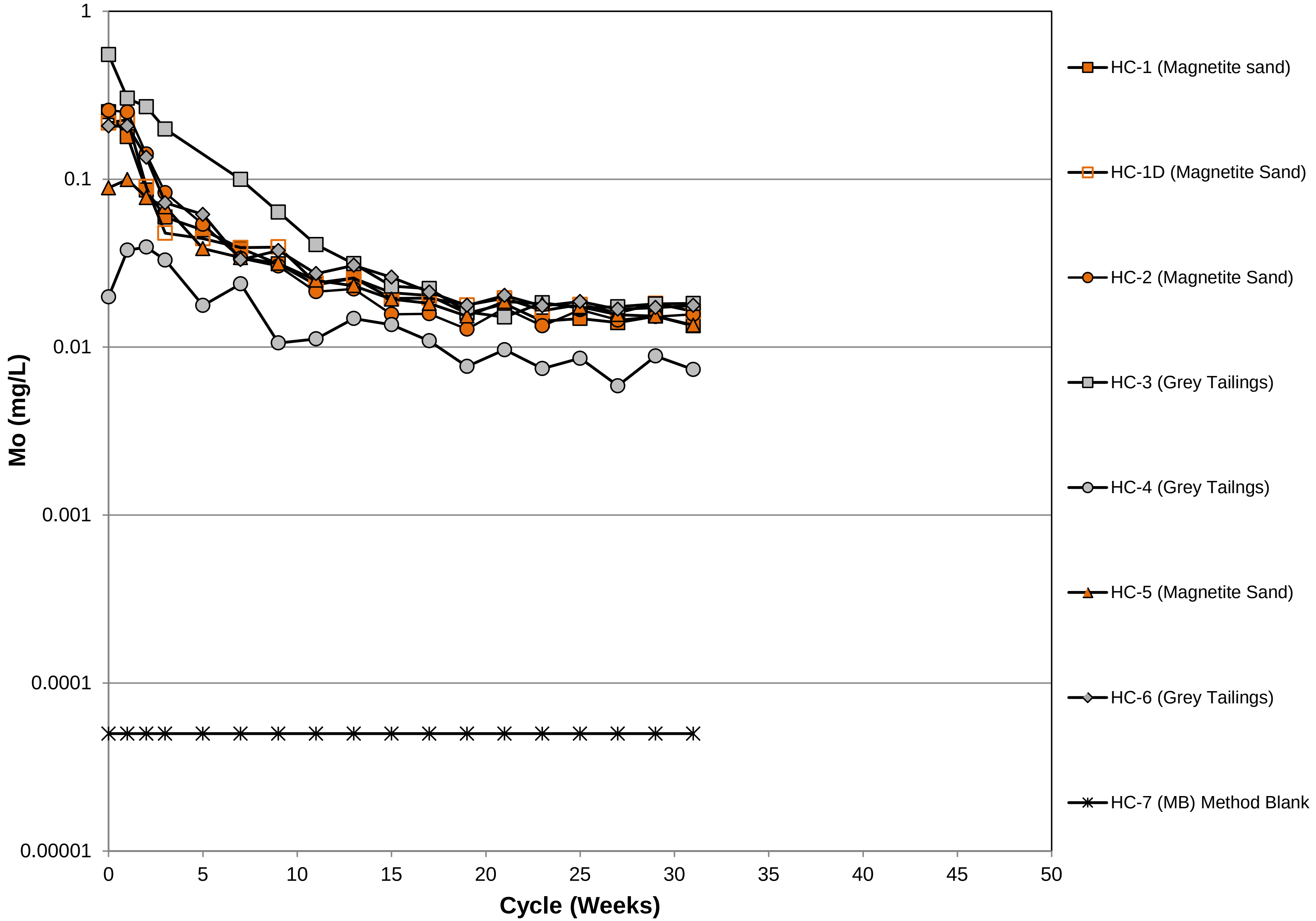

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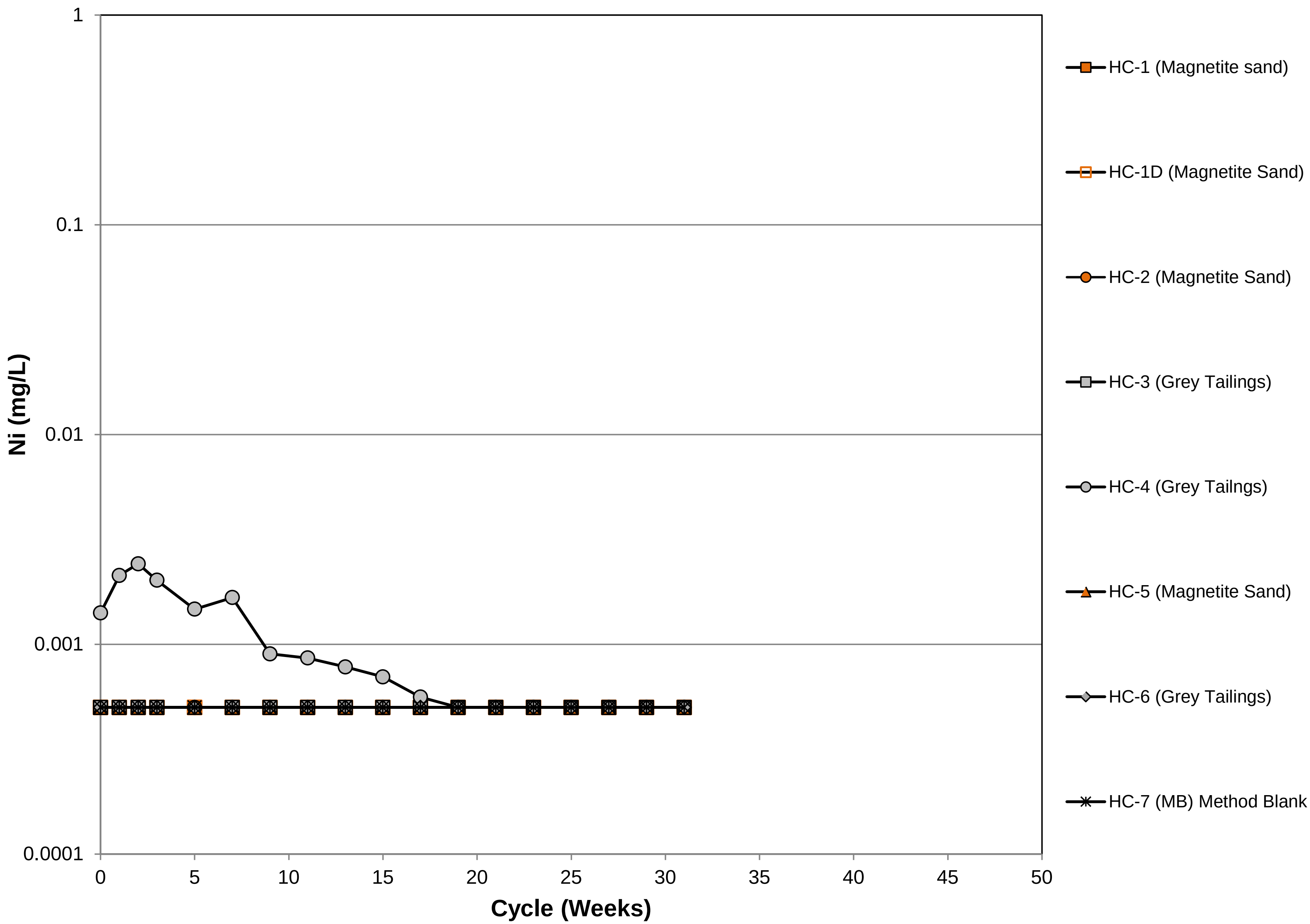

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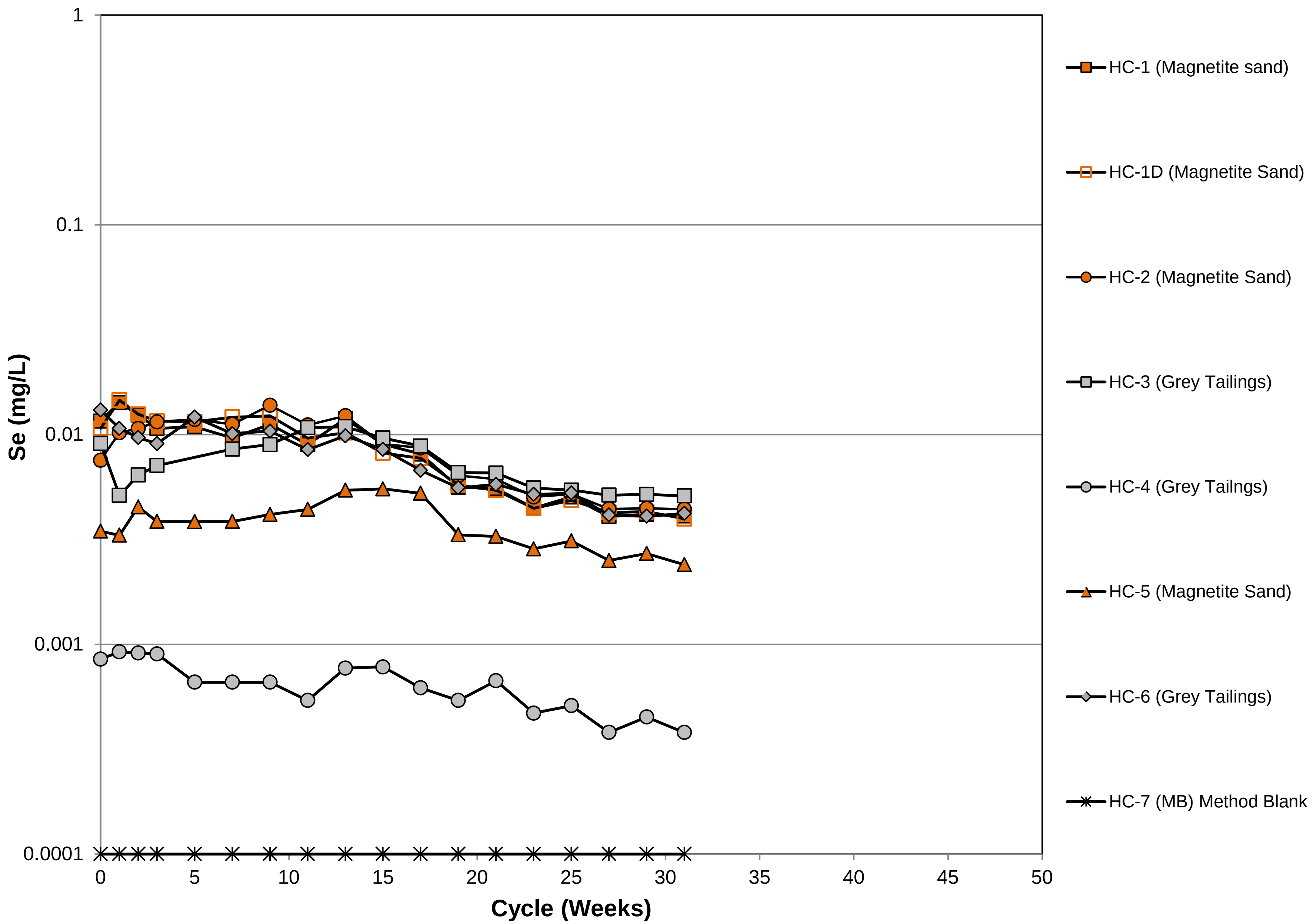

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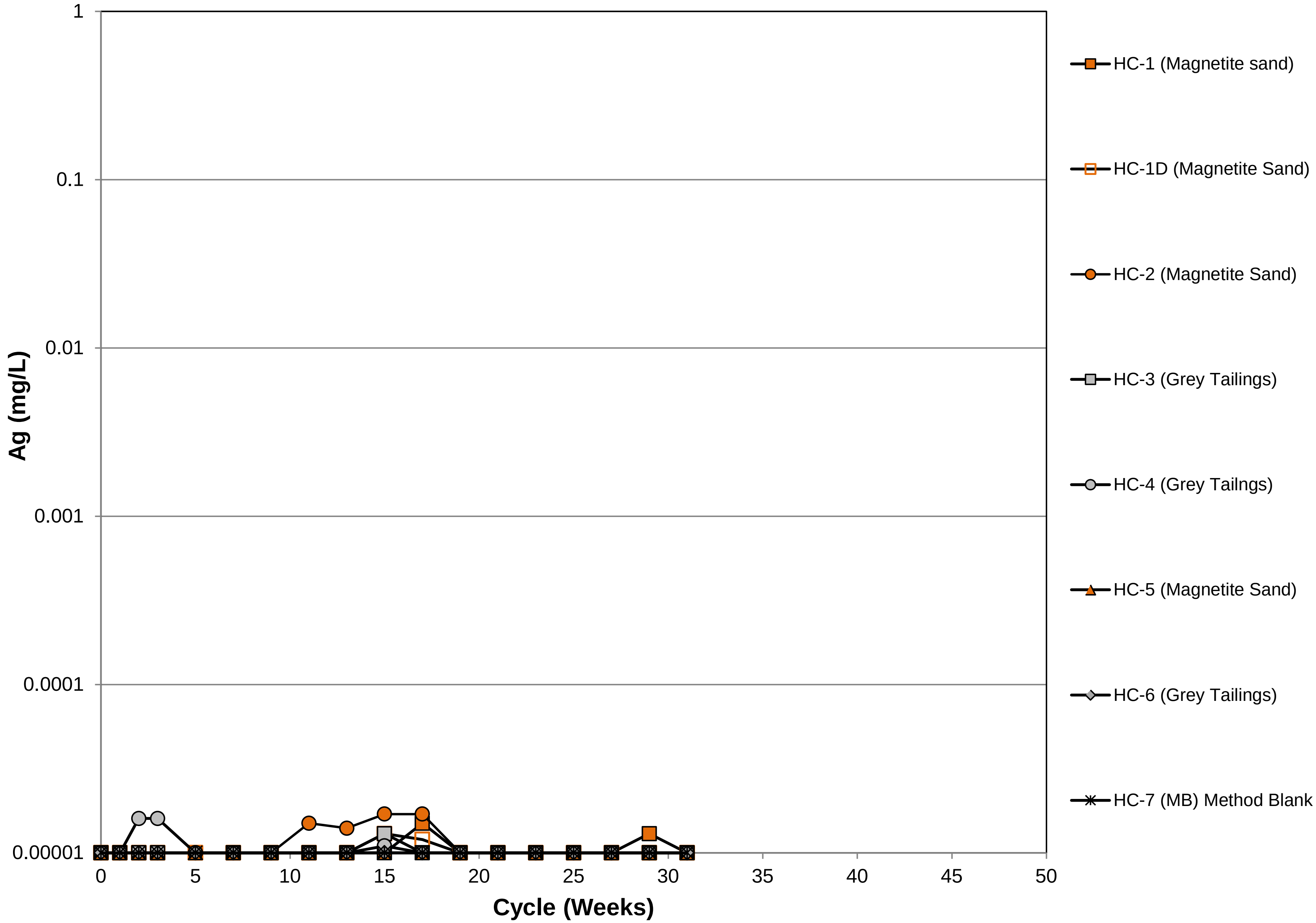

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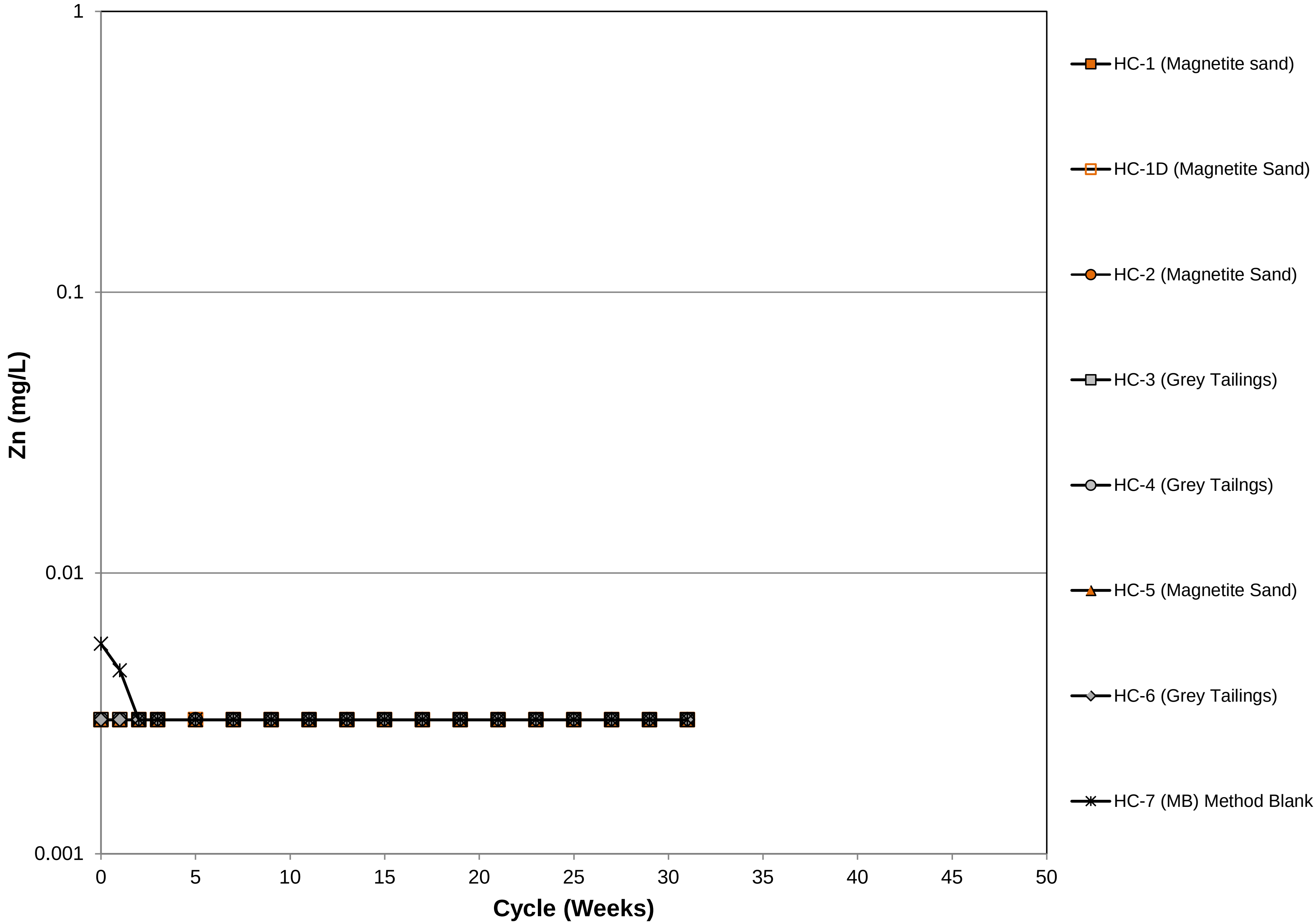

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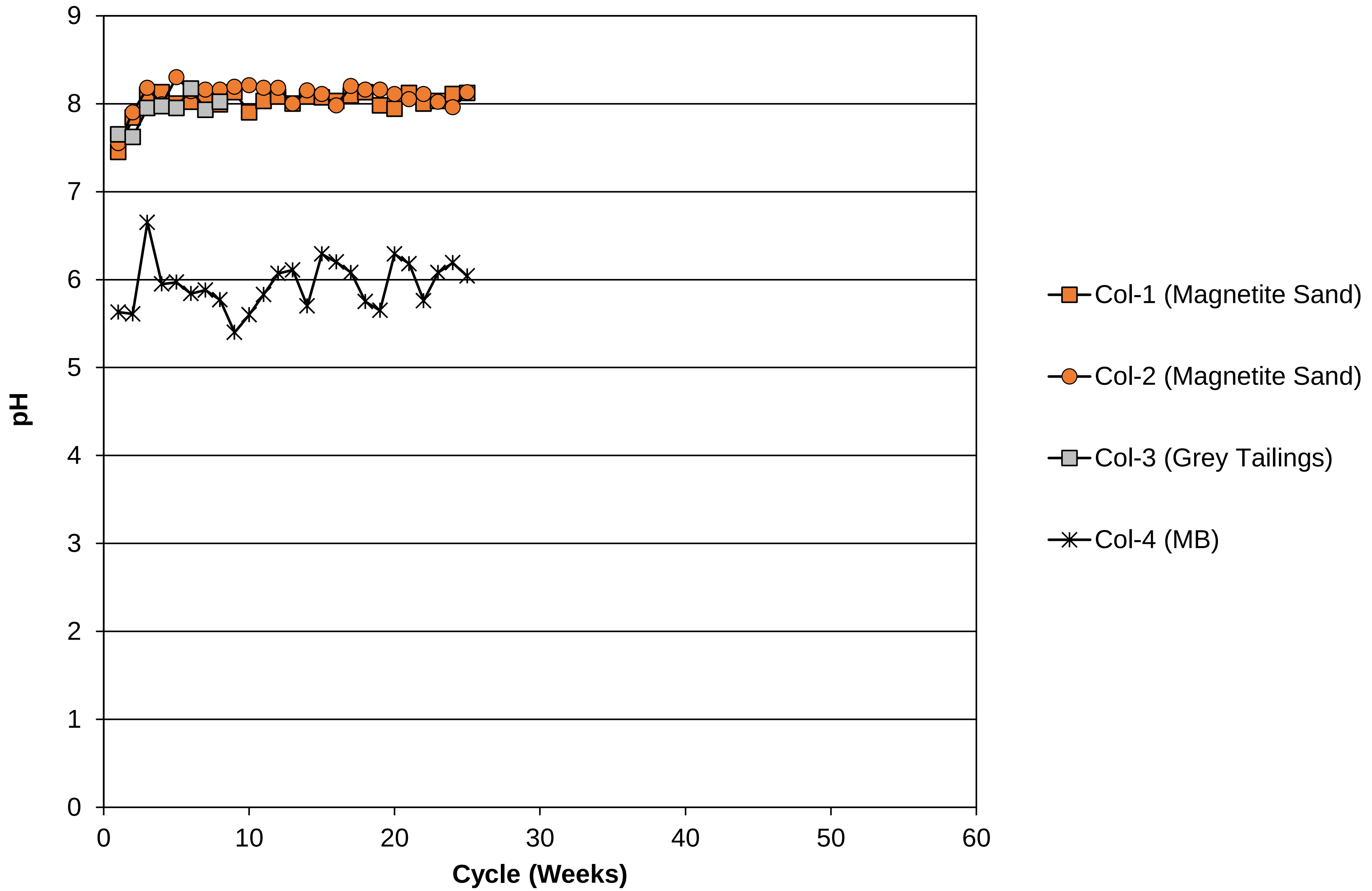
Appendix D – Leaching Rates for Humidity Cells and Columns

Kinetic Test	Tailings Type	Cl mg/kg/wk	F mg/kg/wk	NO_3 mg/kg/wk	NO_2 mg/kg/wk	SO_4 mg/kg/wk	Al mg/kg/wk	As mg/kg/wk	B mg/kg/wk	Cd mg/kg/wk	Co mg/kg/wk	Cu mg/kg/wk	Fe mg/kg/wk	Pb mg/kg/wk	Mn mg/kg/wk	Hg mg/kg/wk	Mo mg/kg/wk	Ni mg/kg/wk	Se mg/kg/wk	Ag mg/kg/wk	Zn mg/kg/wk
HC-1	Magnetite Sand	0.31	0.17	0.0036	0.00043	4.1	0.032	0.0021	0.0043	0.0000061	0.000055	0.0021	0.013	0.000022	0.0045	0.0000022	0.007	0.00022	0.0024	0.0000047	0.0013
HC-1D	Magnetitie Sand	1.1	0.18	0.0032	0.0006	4.3	0.029	0.0021	0.0044	0.0000064	0.000044	0.0021	0.013	0.000022	0.0038	0.0000022	0.0078	0.00022	0.0024	0.0000046	0.0013
COL-1	Magnetitie Sand	0.05	0.087	0.00055	0.000099	5.8	0.00088	0.00055	0.0015	0.0000061	0.0000099	0.0023	0.003	0.000005	0.000089	0.0000005	0.015	0.000053	0.0013	0.00000099	0.0003
HC-2	Magnetite Sand	1.1	0.14	0.0043	0.00049	5	0.034	0.0025	0.0044	0.0000046	0.000043	0.0025	0.013	0.000023	0.0038	0.0000024	0.0066	0.00022	0.0025	0.0000049	0.0013
COL-2	Magnetite Sand	0.051	0.057	0.00057	0.0001	1.7	0.0016	0.00099	0.0016	0.0000016	0.00001	0.0013	0.003	0.000005	0.000079	0.0000005	0.0064	0.00005	0.00059	0.000001	0.0003
HC-3	Grey Tailings	0.8	0.15	0.004	0.00044	11	0.032	0.0038	0.0062	0.0000045	0.000044	0.002	0.013	0.000022	0.0022	0.0000023	0.0081	0.00022	0.0028	0.0000046	0.0013
COL-3	Grey Tailings	0.2	0.043	0.0029	0.000099	12	0.0029	0.00036	0.0038	0.0000019	0.0000099	0.00052	0.003	0.0000049	0.00036	0.00000049	0.016	0.000049	0.00067	0.00000099	0.0003
HC-4	Grey Tailings	1.7	0.045	0.34	0.0052	12	0.025	0.00083	0.0076	0.0000046	0.000046	0.023	0.027	0.000027	0.00096	0.0000036	0.004	0.00024	0.00024	0.0000046	0.0014
HC-5	Magnetite Sand	1.8	0.056	0.0065	0.00076	9.9	0.025	0.0013	0.0049	0.0000048	0.000048	0.0036	0.015	0.000024	0.00082	0.0000024	0.008	0.00024	0.0016	0.0000048	0.0014
HC-6	Grey Tailings	1.1	0.11	0.003	0.00045	4.3	0.029	0.0022	0.0046	0.0000047	0.000045	0.0027	0.013	0.000022	0.002	0.0000023	0.0086	0.00022	0.0024	0.0000045	0.0013

Appendix E – Column Concentrations Charts



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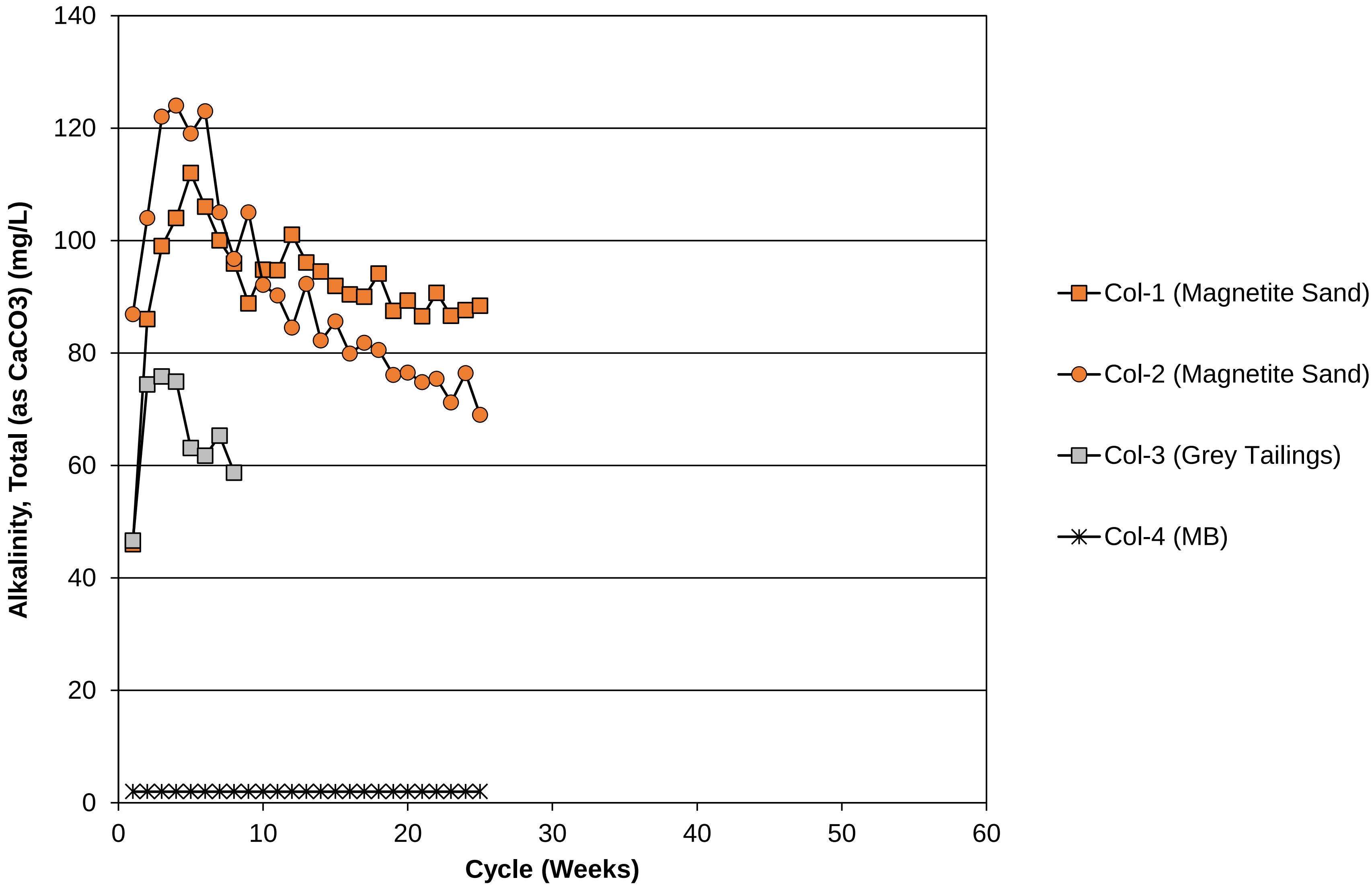

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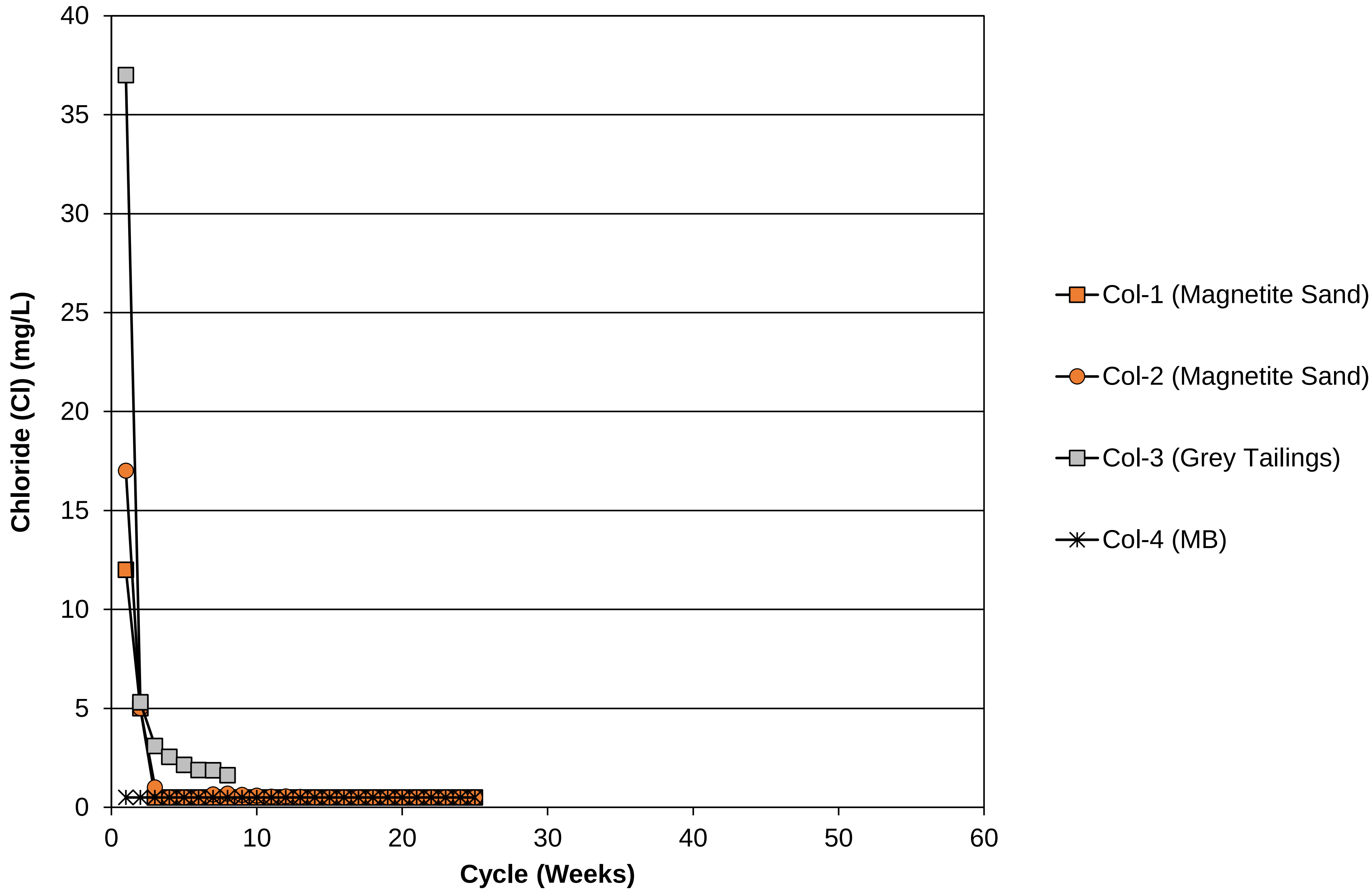

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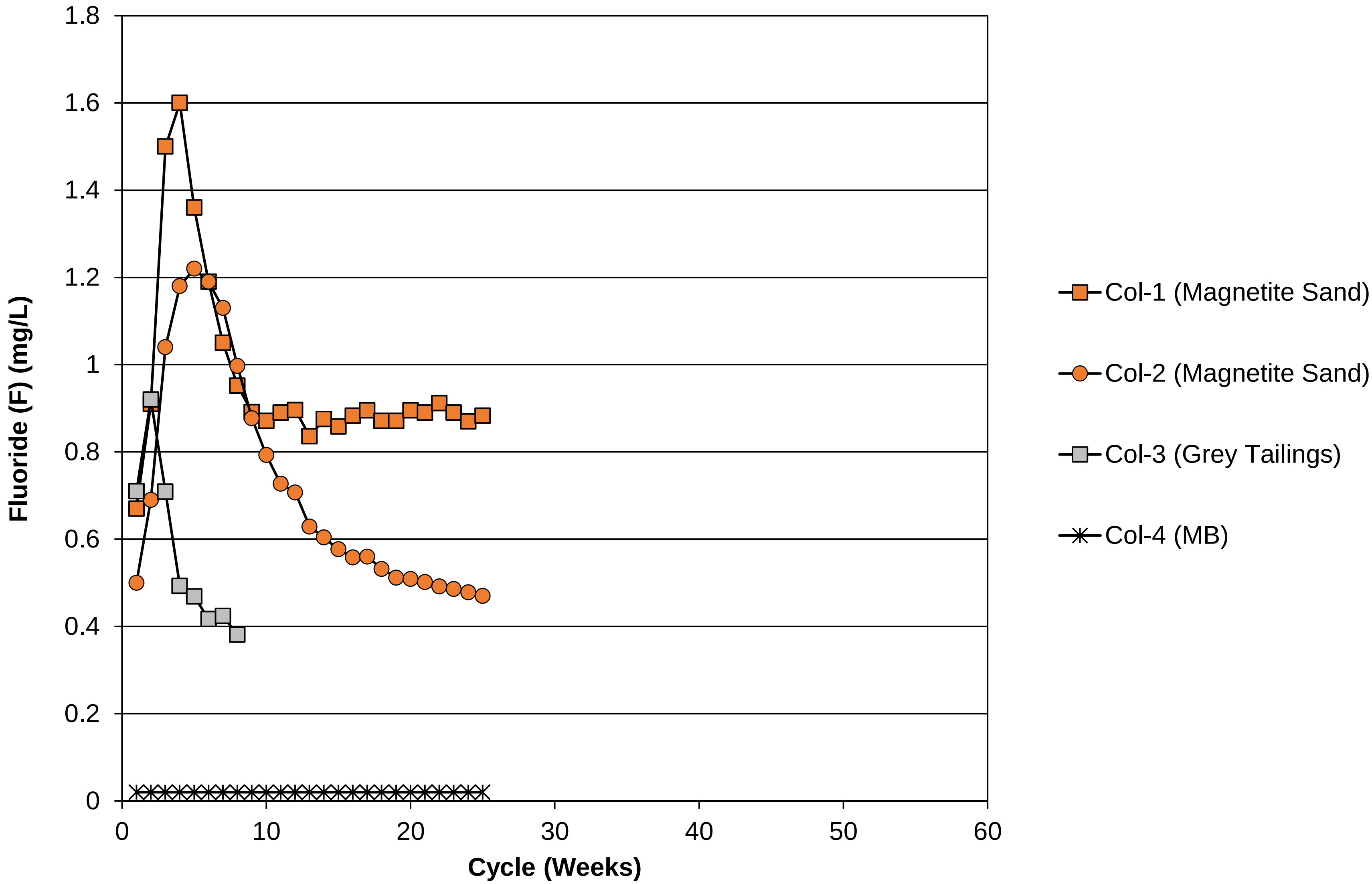

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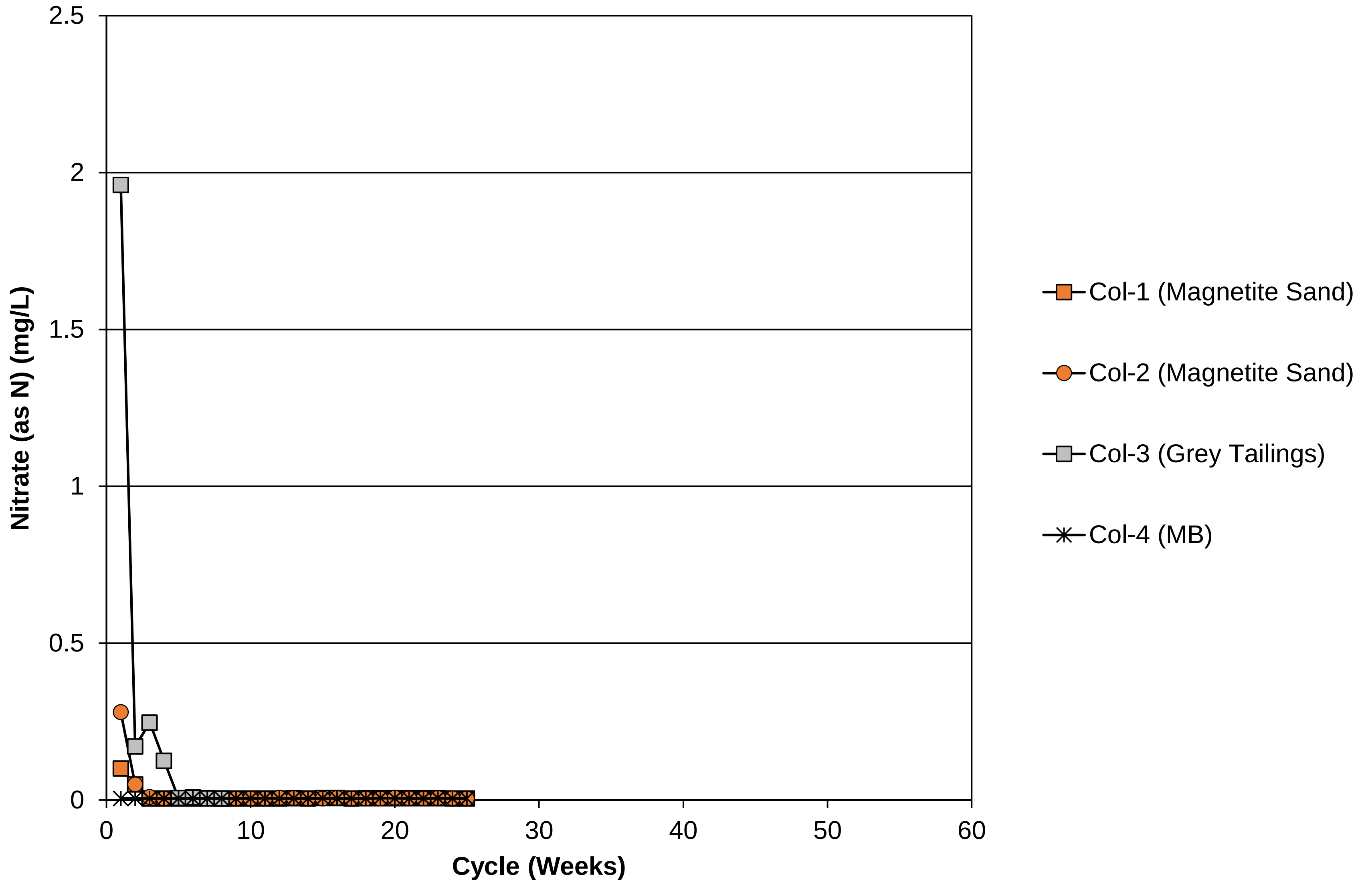

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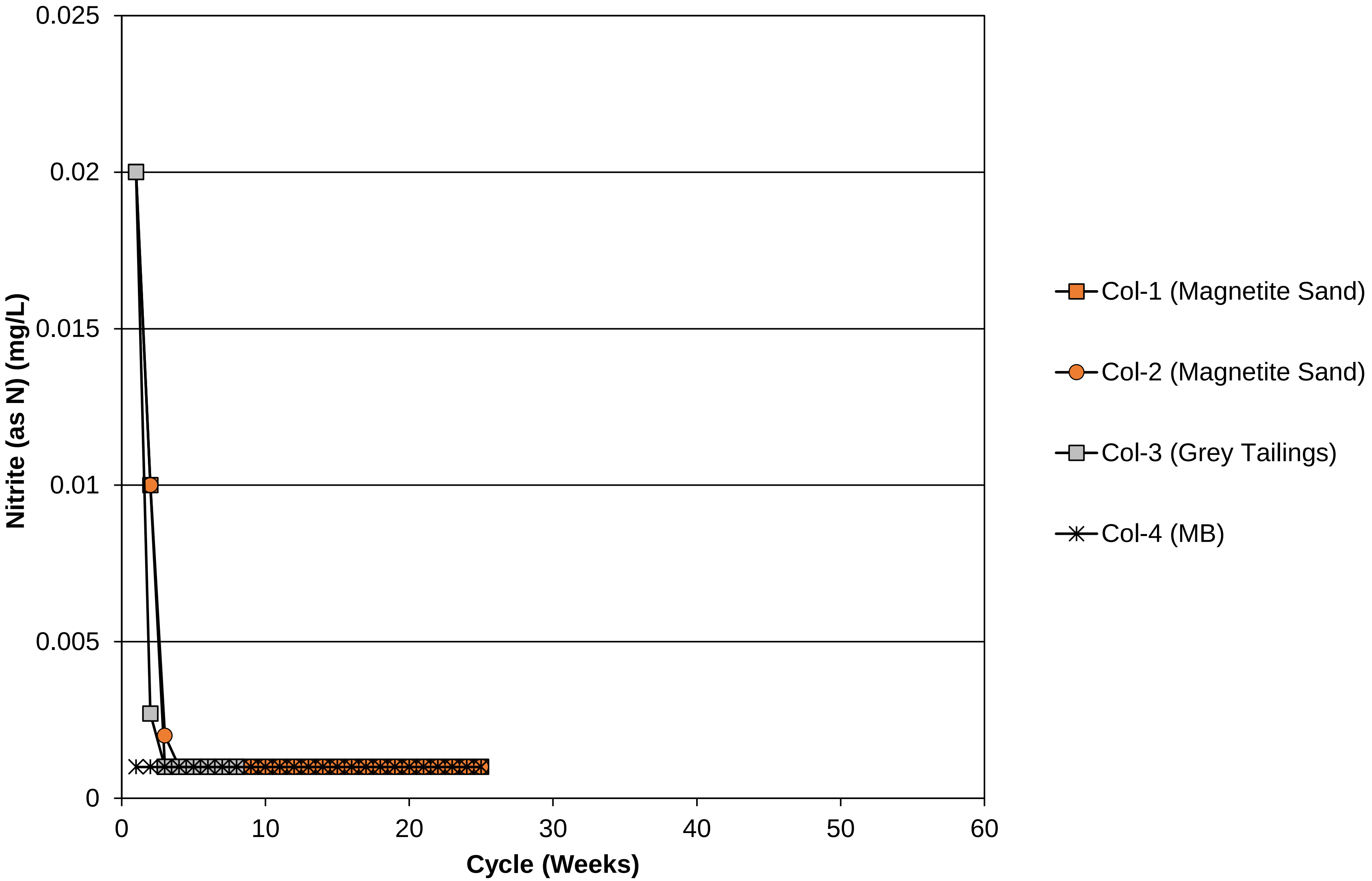

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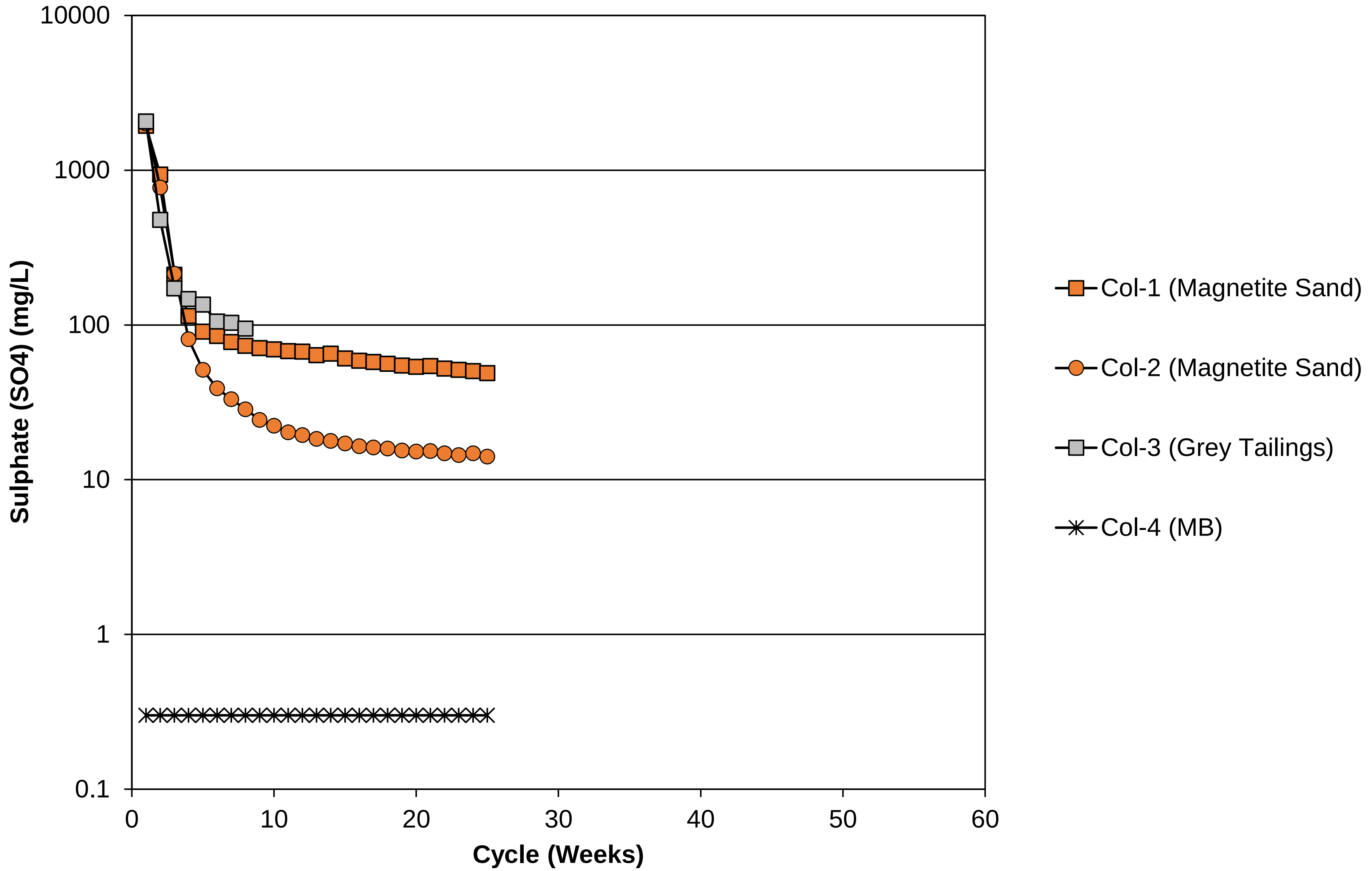

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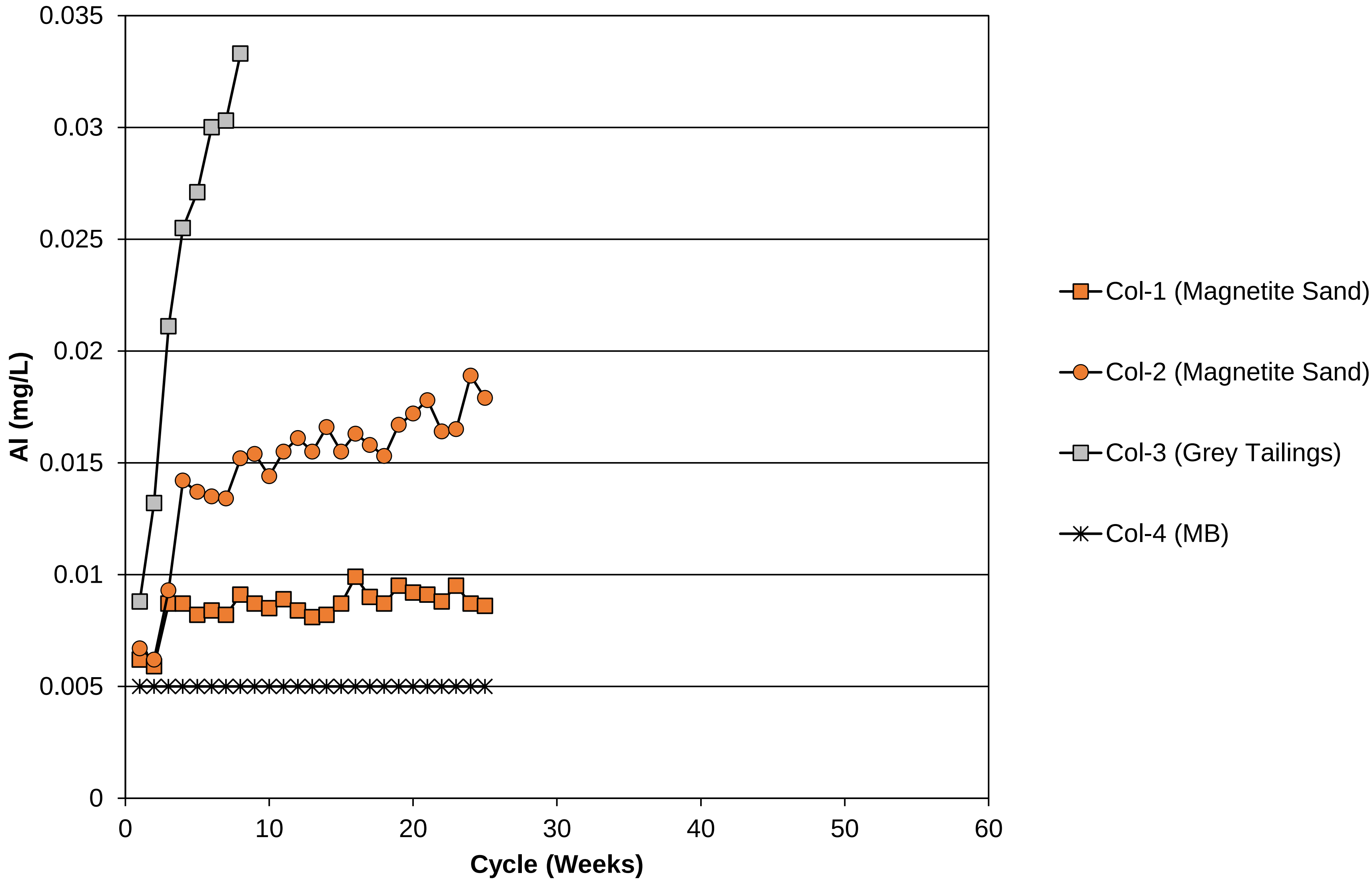

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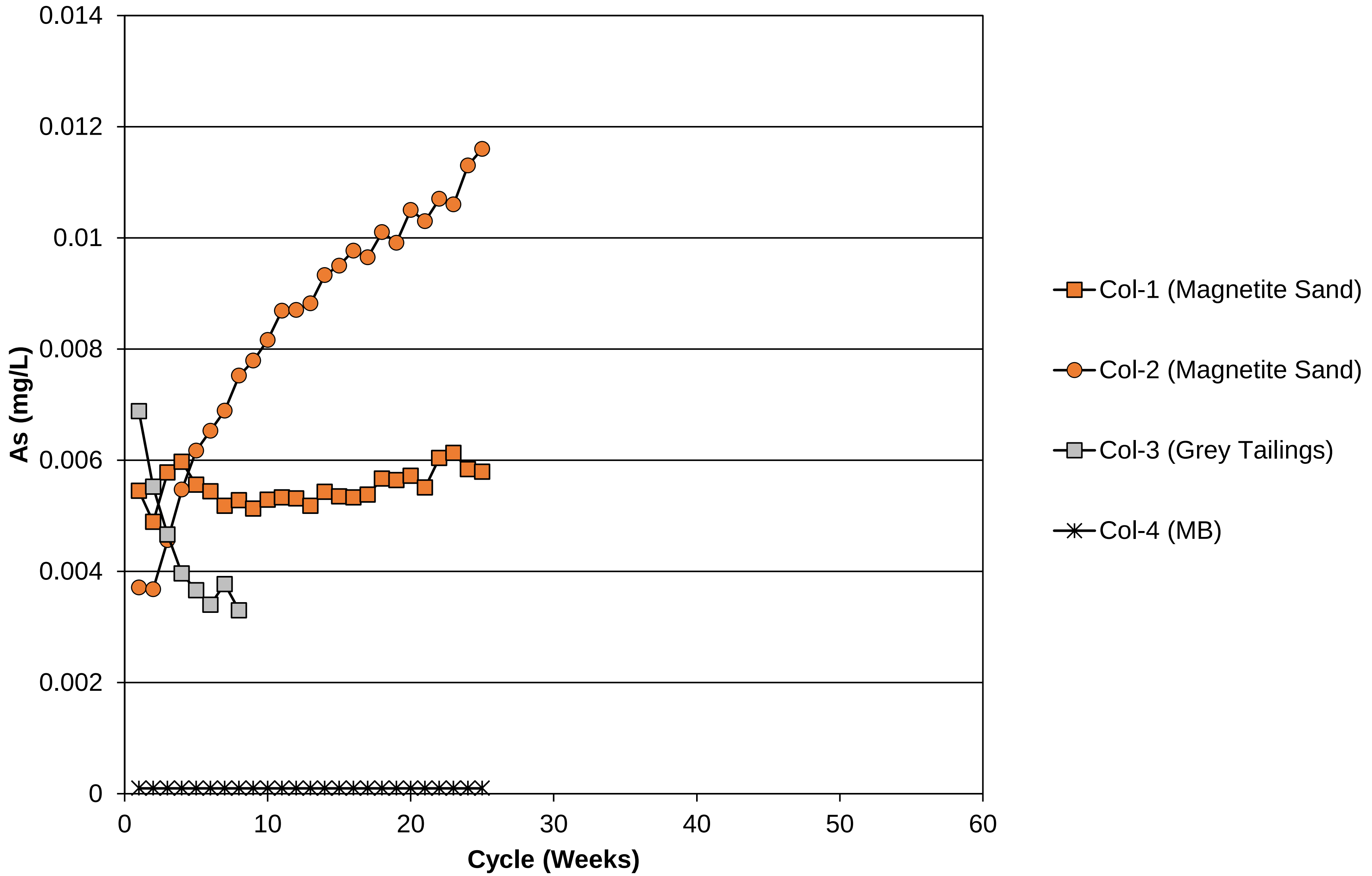

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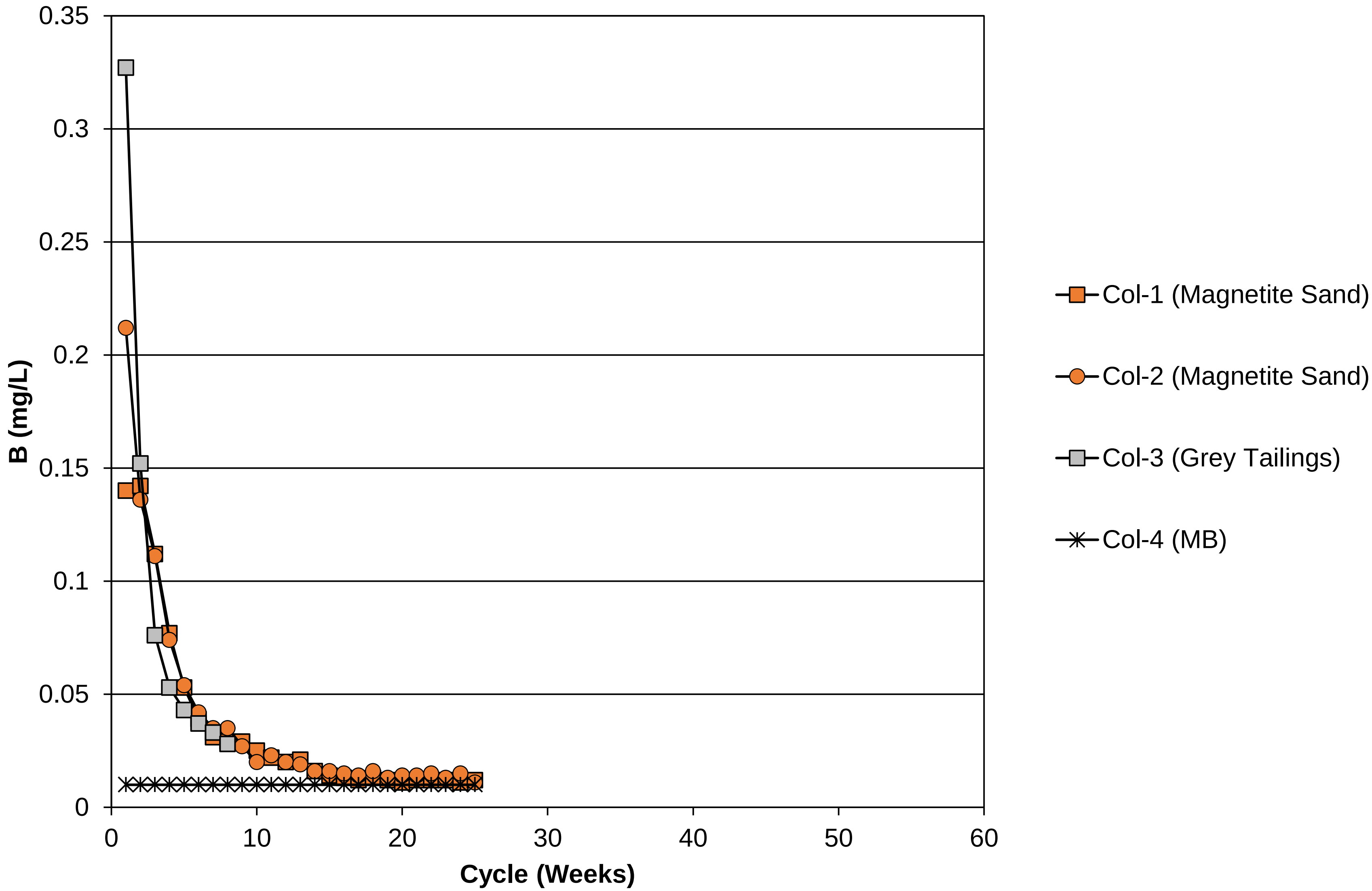

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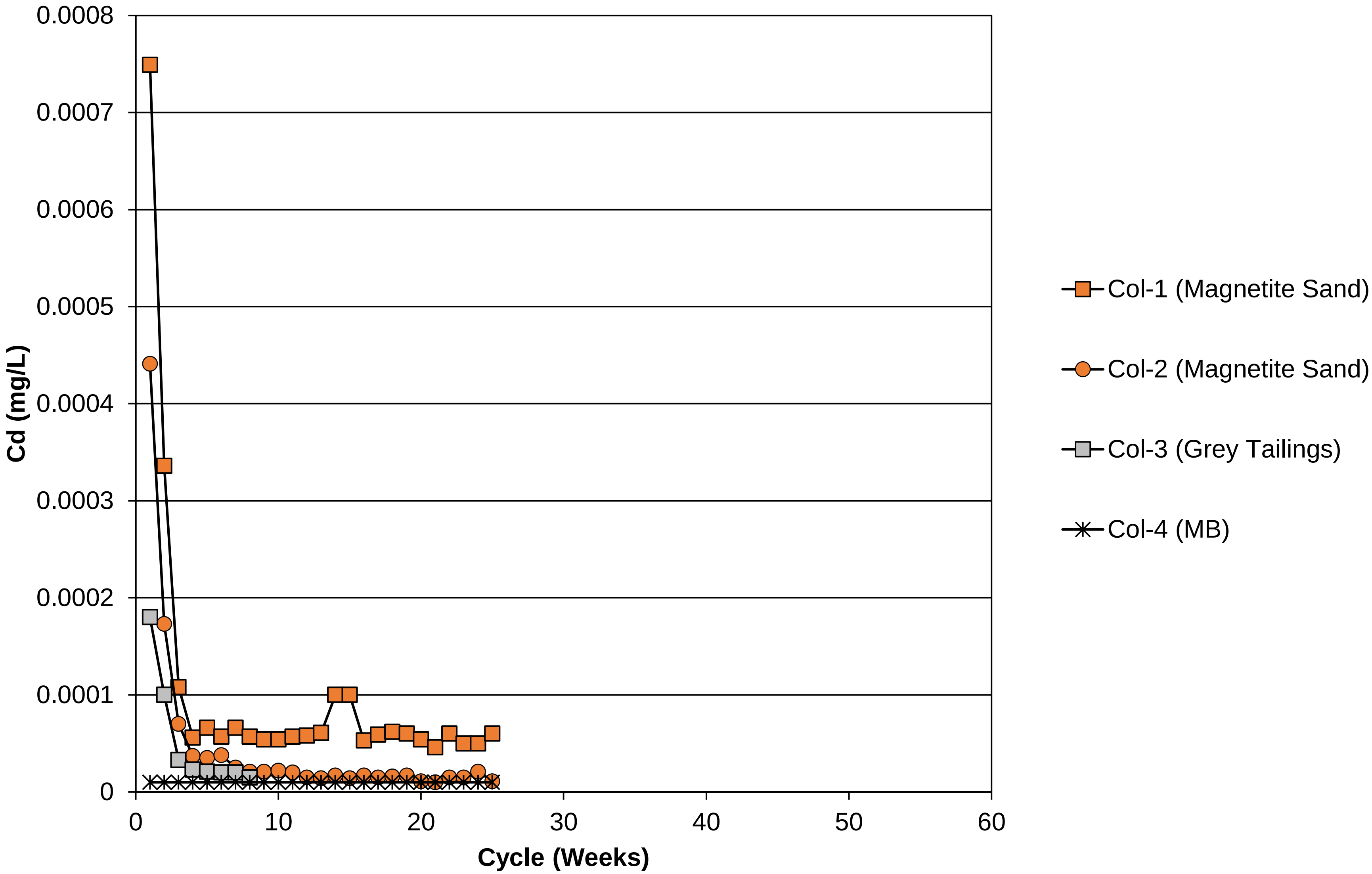

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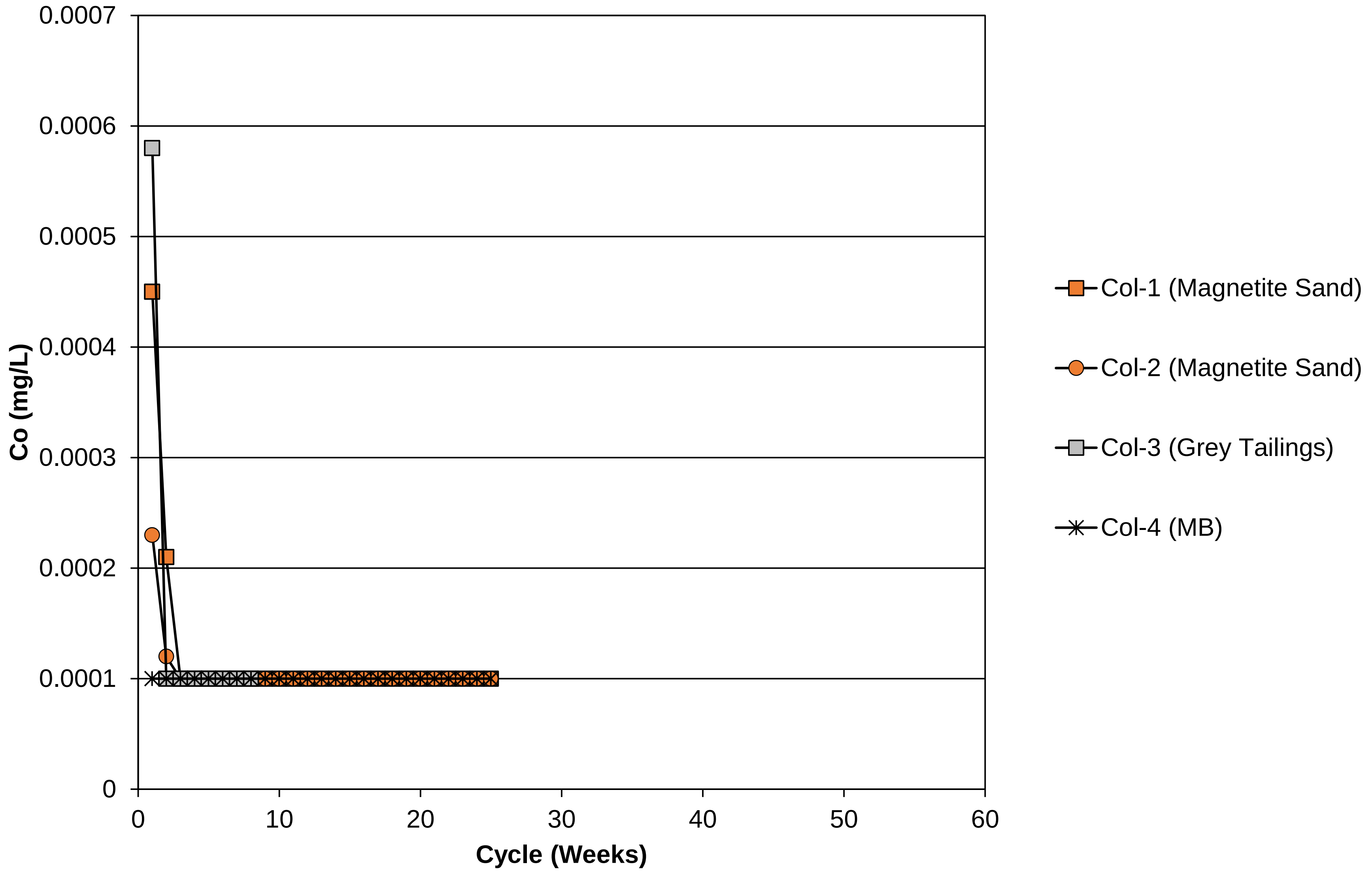

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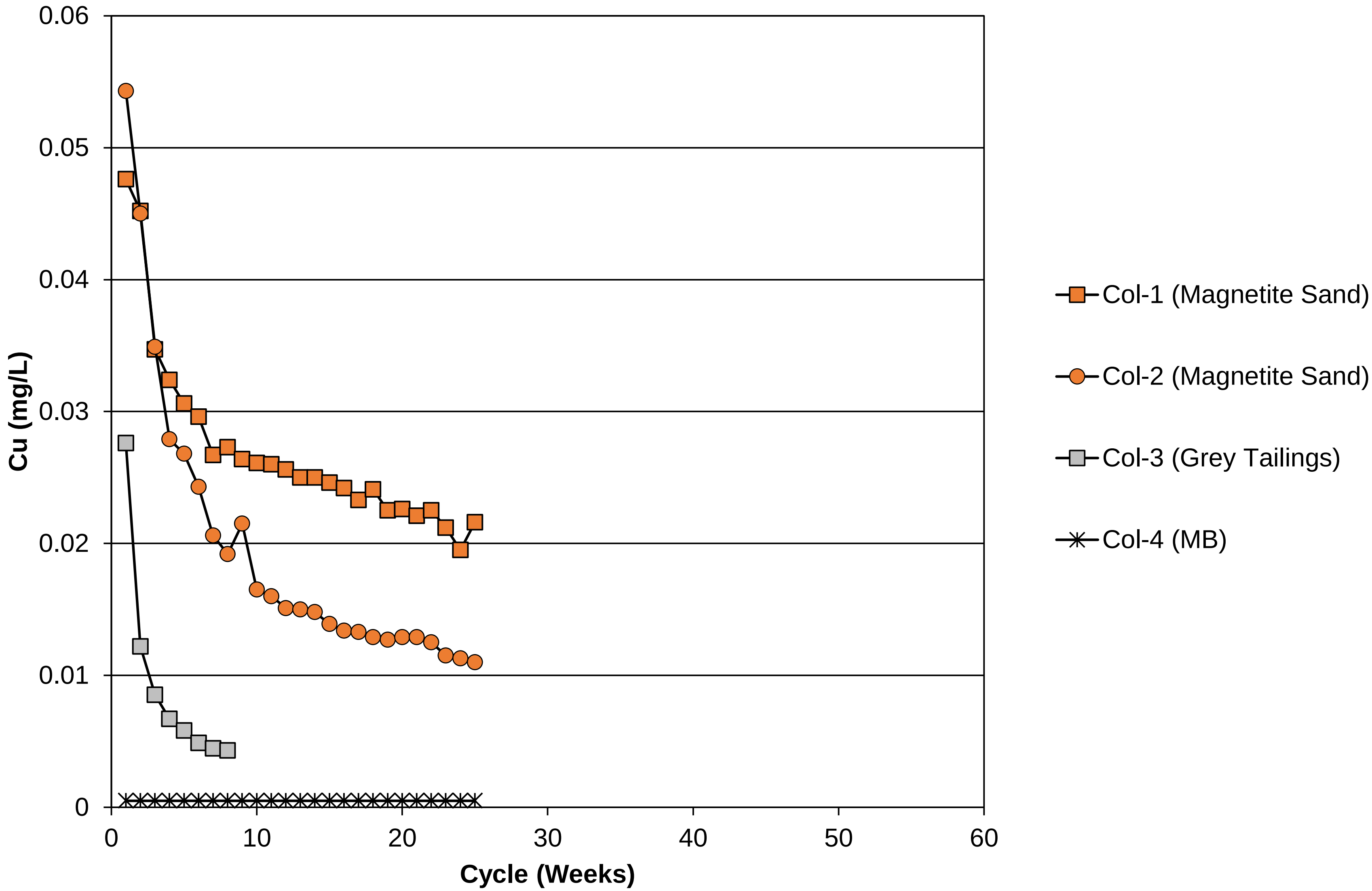

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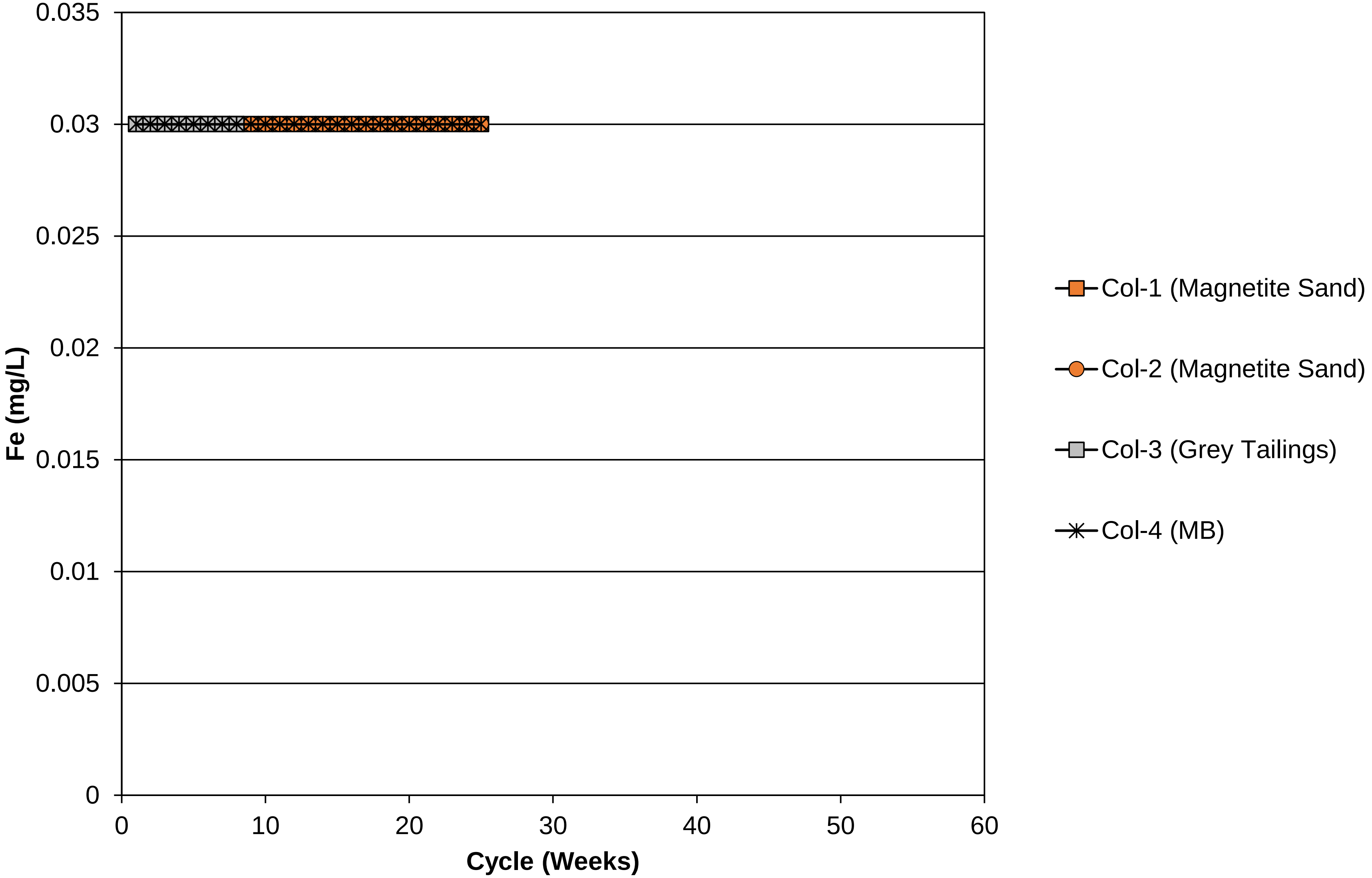

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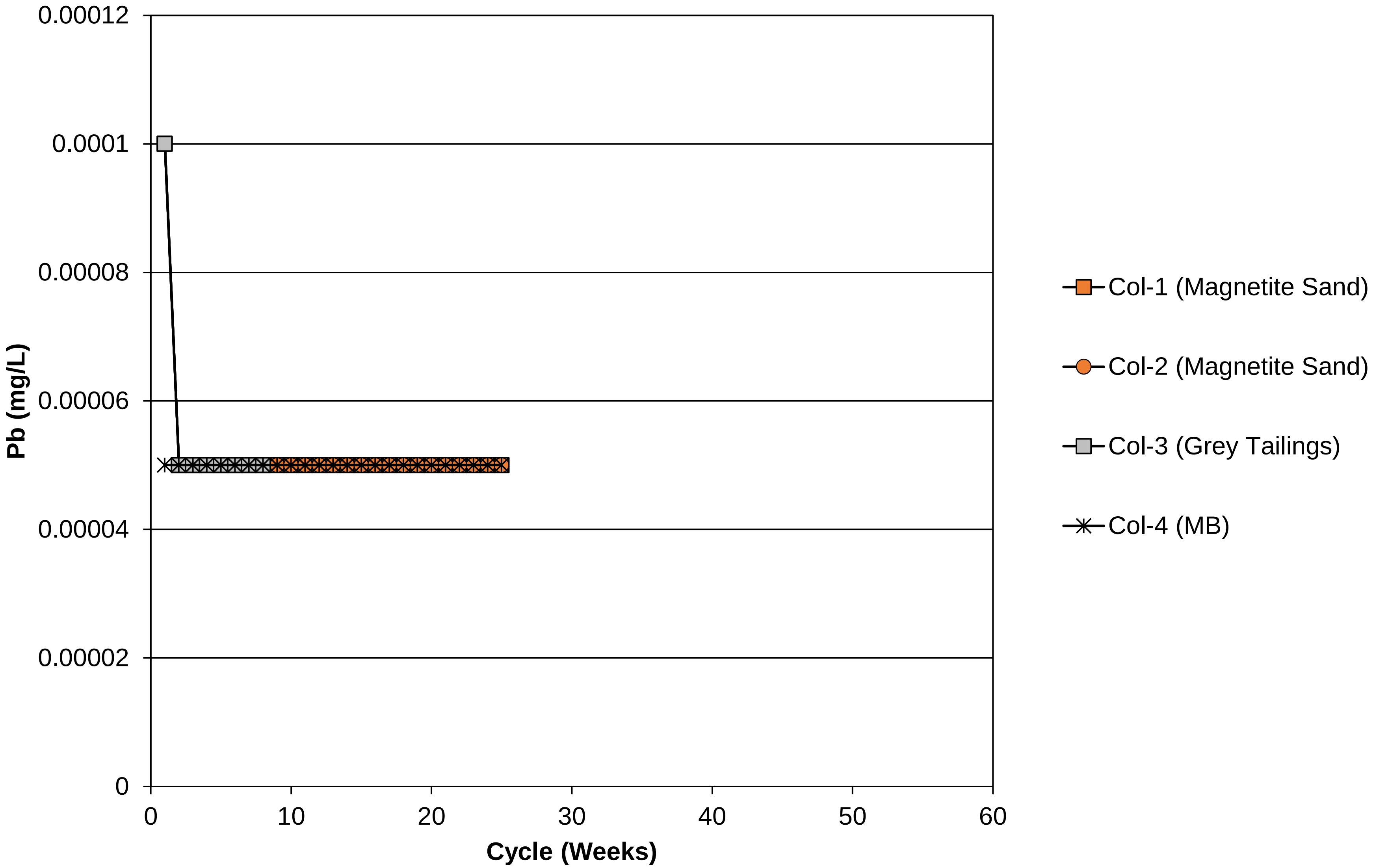

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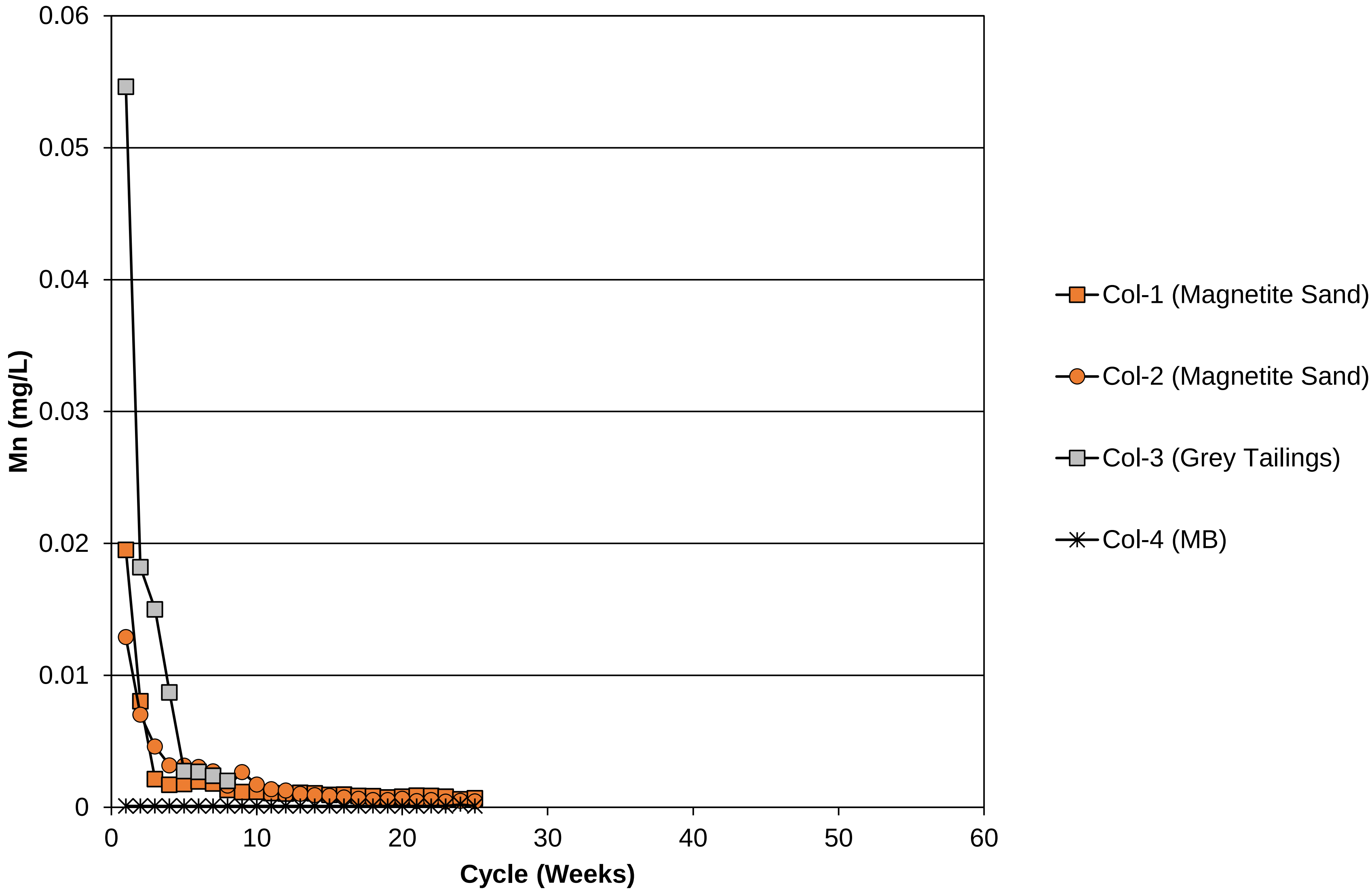

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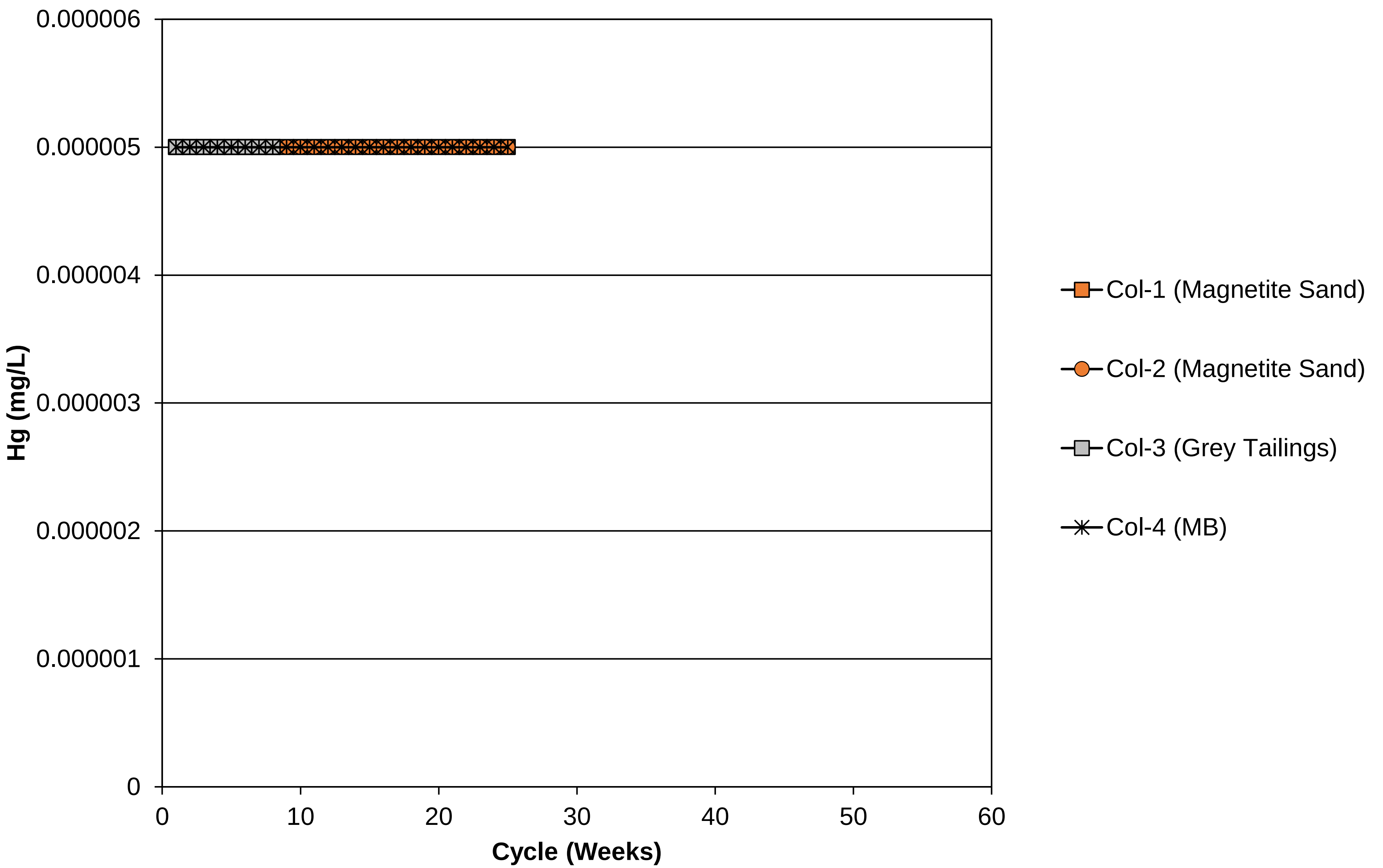

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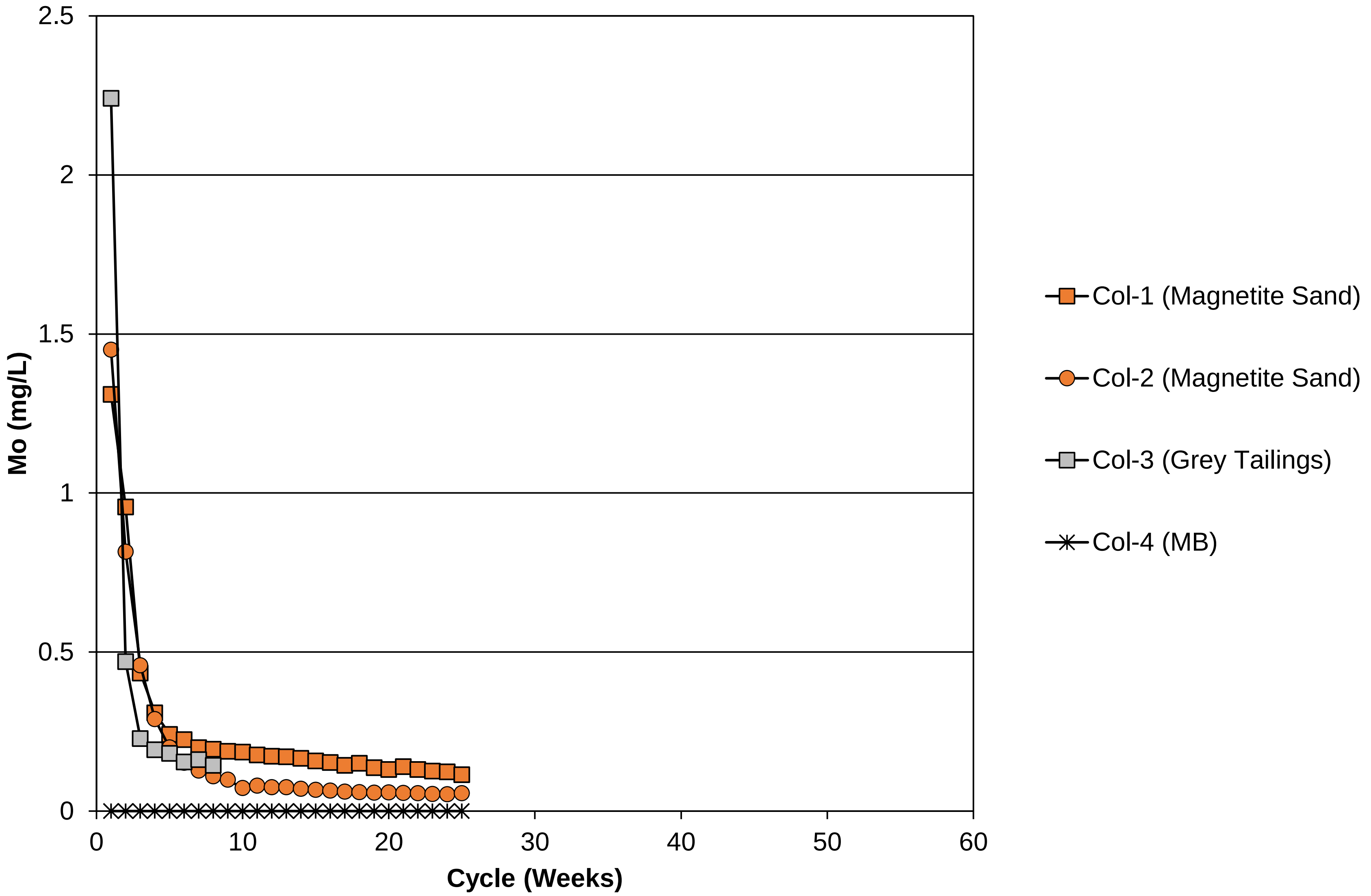

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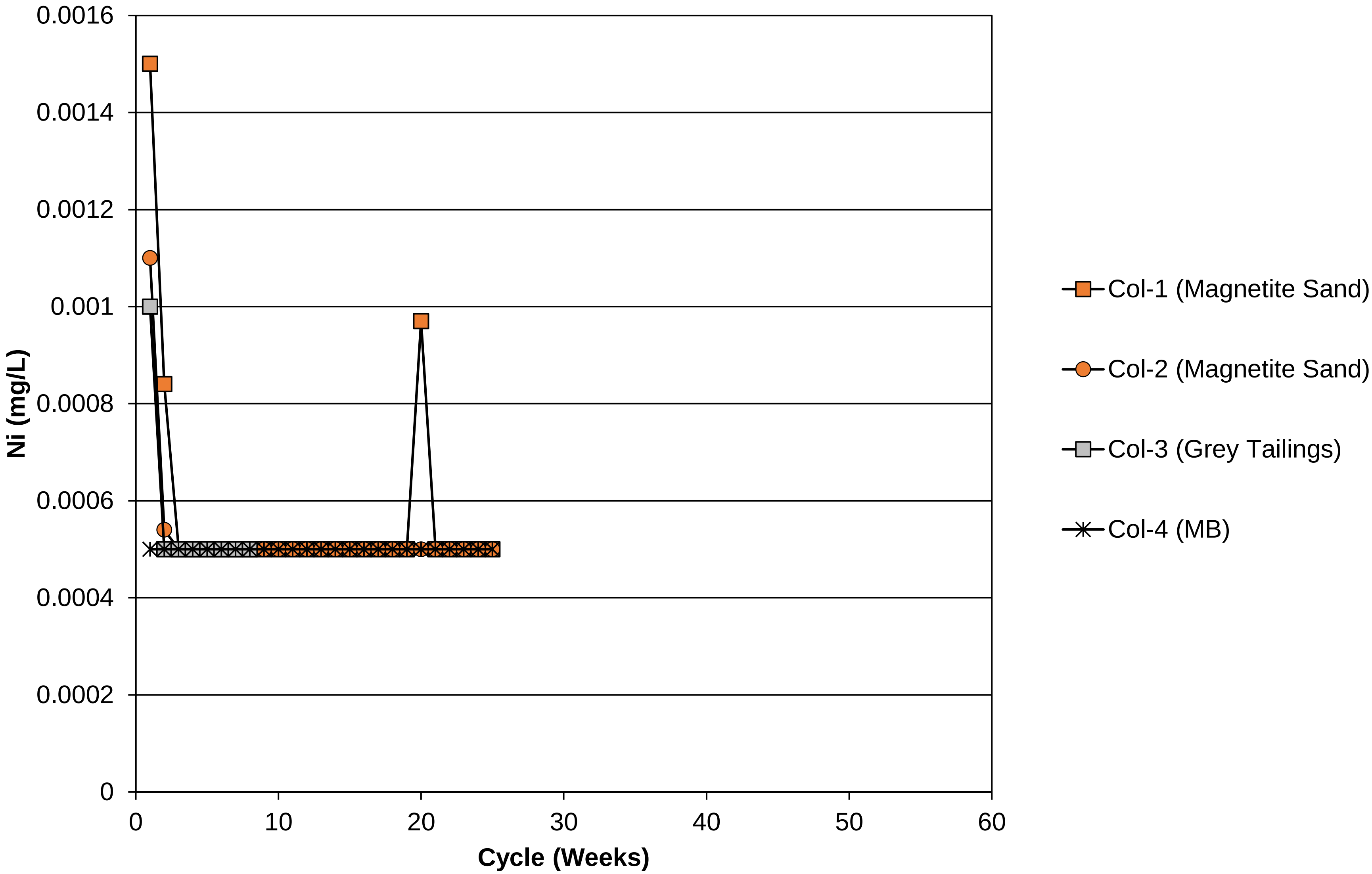

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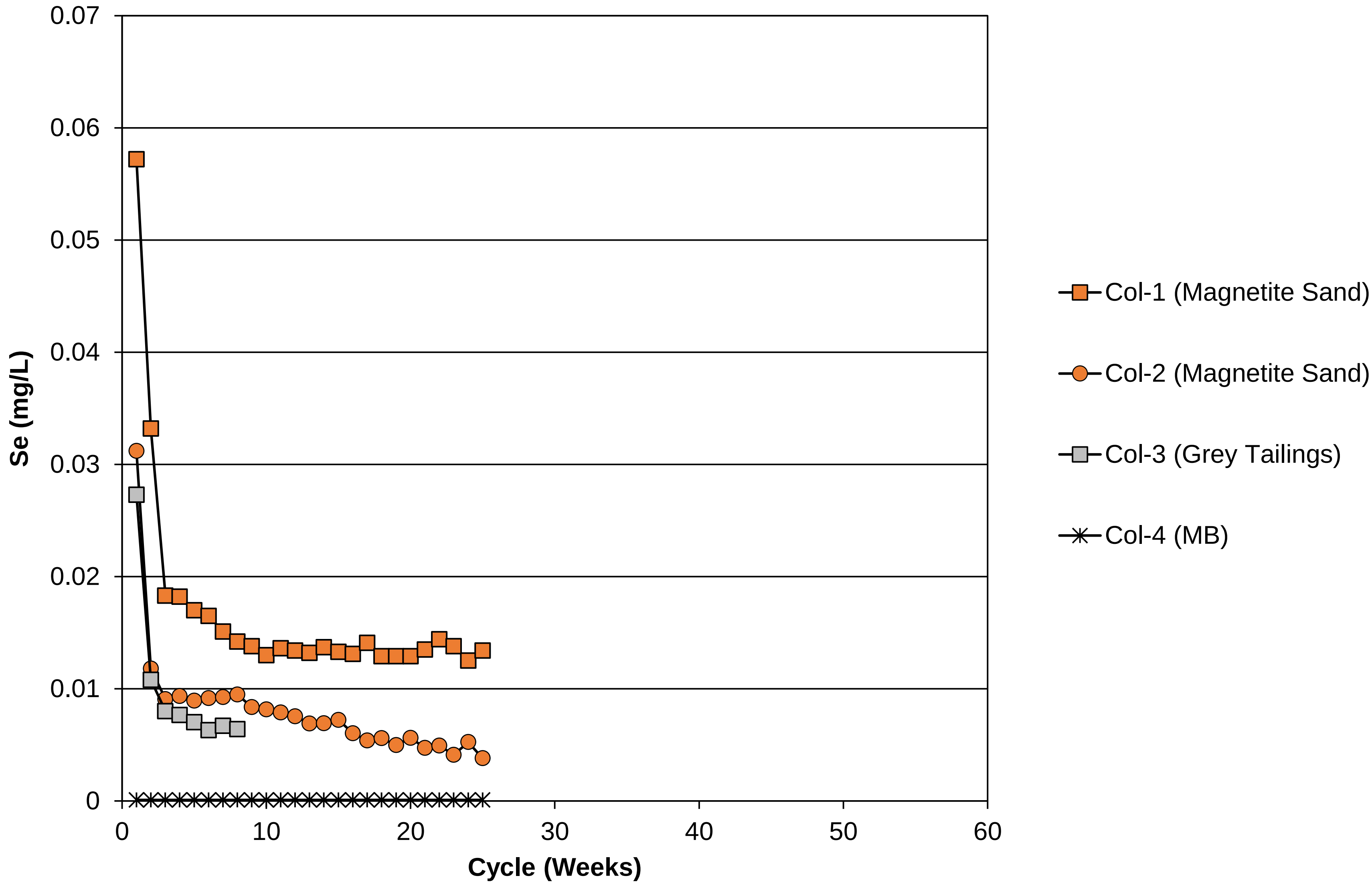

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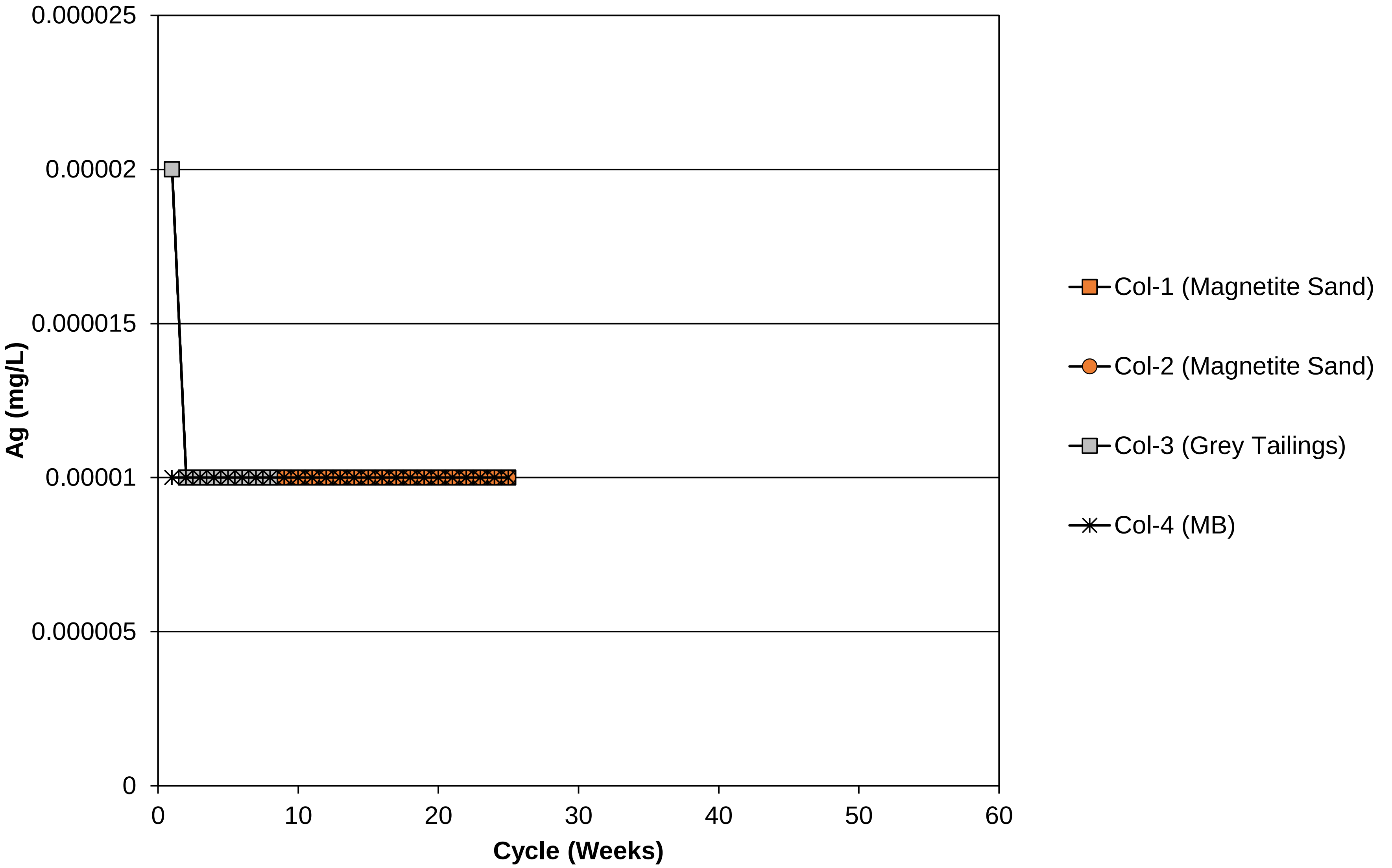

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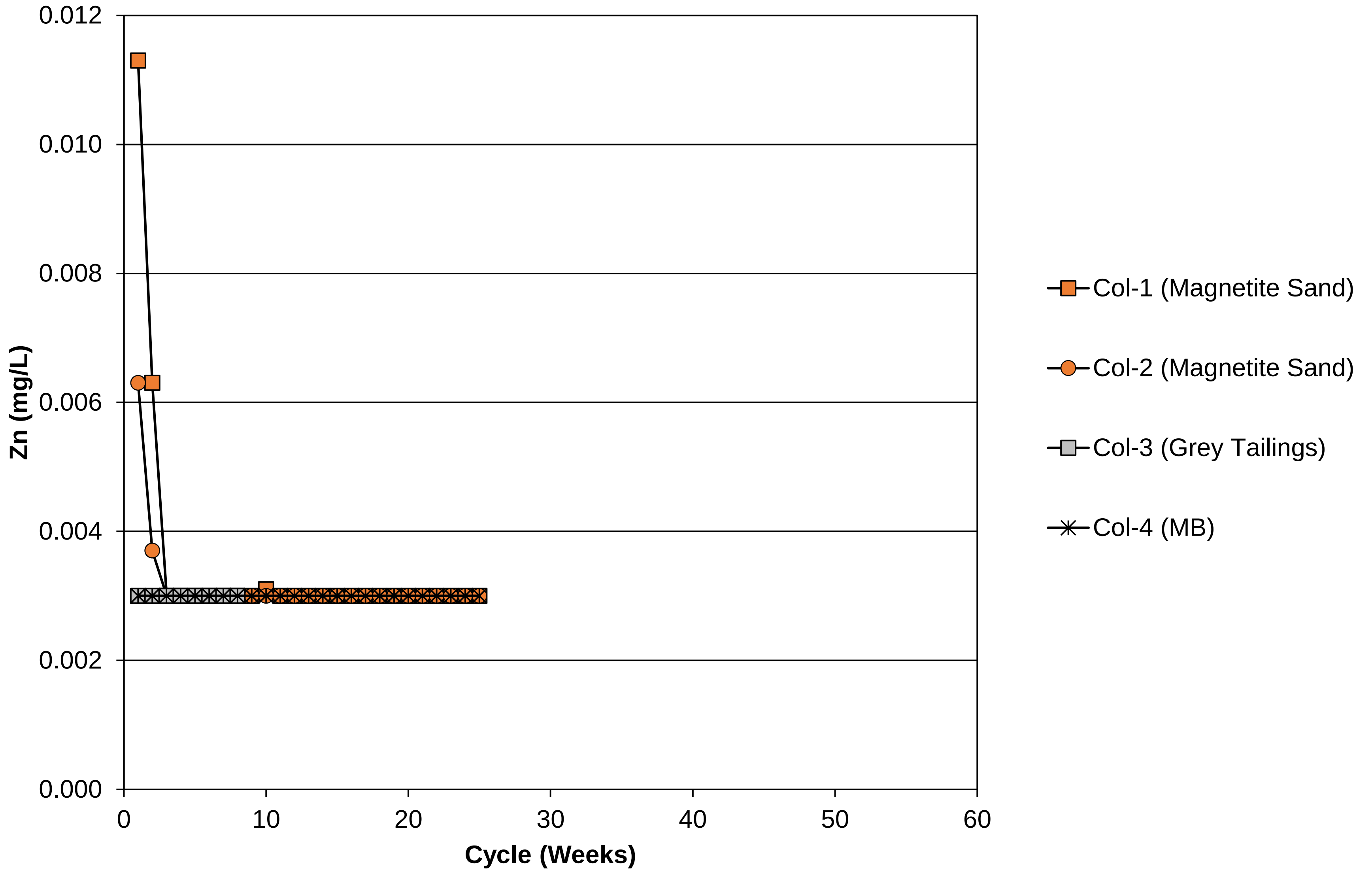

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