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The Effects of Wetting and Drying on Chromium and Other Metal Mobility

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Matthew Robert Harold

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Major Professor's Signature

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Date

THE EFFECTS OF WETTING AND DRYING ON CHROMIUM AND OTHER METAL MOBILITY

By

Matthew Robert Harold

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ABSTRACT

THE EFFECTS OF WETTING AND DRYING ON CHROMIUM AND OTHER METAL MOBILITY

By

Matthew Robert Harold

This study looks at the effects that wetting and drying has on Cr mobility in wetland soils. The source of the chromium was a former leather tannery that operated from the early 1900's to 1958. At the wetland site, the dominant form of Cr is Cr (III). A previous study done at the wetland site reported that soils that underwent saturation changes in the field released higher levels of chromium to solution during laboratory leaching studies. This study investigated four questions (1) is there evidence that wetting and drying enhances chromium mobility? (2) does the duration of drying affect chromium mobility? (3) do aerobic microbes play a role in chromium mobility during wetting and drying? (4) how does chromium behavior compare to other elements?

The results of this study indicate that wetting and drying affects chromium mobility. Concentrations of chromium increased under wetting and drying cycles and concentrations of chromium decreased when the soils are always wet. Soils that were not completely dried did not behave the same as samples that were always wet or completely dried. From the results of this study, the role of microbes in the mobilization of chromium can neither be supported nor denied. Finally, chromium behaves differently than Fe, Mn, and Sr under wetting and drying conditions.

To my wife Donna and to my parents and my brother Dave, without whose support and patience I could not have maintained the will to see this project to its conclusion.

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INTRODUCTION

Chromium, mainly in the form of Cr (III), was discharged as waste from a tannery into a wetland from the early 1900's to 1958. The elevated concentrations of chromium in the wetland soils and sediments were a cause for concern because the negative impact of chromium on the ecosystem and human health (Ellis, 1999). Chromium has two redox states, Cr (III) and Cr (VI). Cr (III) is the less toxic form of chromium found in the environment. Cr(III) was the dominant form discharged at the former tannery site (Icopini et al., 1997, 1998, and 1999). In the aqueous phase, trivalent chromium is kinetically stable and is found as $Cr(OH)^{2+}$ and organic complexes (Hem, 1985). In the aqueous phase, trivalent chromium can become hexavalent chromium via slow oxidation (Takacs, 1988). Manganese oxides can also oxidize trivalent chromium (Hem, 1985). Hexavalent chromium is thermodynamically stable, and hexavalent chromium can become trivalent chromium in the aqueous phase via reduction by S^{2-}, Fe^{2+}, and organic acids (Takacs, 1988).

Chromium concentrations near the tannery were evaluated because of the location of the contamination. The site's close proximity to a major Great Lakes waterway lead to concern for increased mobility of chromium in solution. In addition to being close to a major waterway, there was increased interest for contamination in wetland areas. The hydrology and soils associated with wetland areas pose a greater threat for mobility than sites associated to upland hydrology and soils. The water table was near the surface and in contact to areas contaminated with chromium. Furthermore, wetland soils have a high percent of organic matter relative to upland soils. The high percent of organic matter was of interest because chromium complexes with organic matter. Degradation of the organic matter could lead to an increase in chromium mobility. Processes that would impact the state and mobility of chromium are important for this wetland. One possible process that would impact chromium mobility is wetting and drying. This study investigated the role of wetting and drying on chromium mobility.

1.0 Background of the Site

This section will describe the procedures and findings of Ellis (1999) and Icopini et al. (1997, 1998, and 1999) at the same site location as this study. The site is located in Michigan's Upper Peninsula. It is situated in a wetland area adjacent to a major waterway. Two remediation strategies that were proposed for the wetland were the (1) removal of the soil from the site and (2) in situ stabilization of the chromium in the soils. To assess the feasibility of in situ stabilization of chromium in the soils, Ellis (1999) and Icopini et al. (1997, 1998, and 1999) utilized field and laboratory tests to investigate the current state of chromium at the wetland and possible mechanisms for its release from the soil.

Ellis (1999) and Icopini et al. (1997, 1998, and 1999) took soil samples throughout the wetland at three depth intervals (0-0.5 ft, 1-1.5 ft, and 3-3.5 ft) to determine the oxidation state and spatial distribution of chromium. In addition, Ellis (1999) and Icopini et al. (1997, 1998, and 1999) did selective chemical extractions on the sediments to assess the partitioning of chromium among soil phases at the wetland. From that work, the substrates that control chromium immobilization were determined to be iron oxides, $Cr(OH)_3$, and organic matter. An illustration of the possible roles of these substrates in the cycling of chromium in oxic systems based on theoretical considerations and laboratory studies is presented in Takacs (1988). Figure 1 shows the mechanisms associated with the sequestering of chromium with different phases (e.g. iron oxides, organic matter, and manganese oxides). Across the sediment/water interface, trivalent chromium is sequestered by $Cr\ (OH)_3$ and $(Fe, Cr)(OH)_3$ by precipitation in the solid phase. Adsorption is the means by which trivalent chromium is sequestered by iron oxides, clays, solid organics, and manganese oxides. In the sediment, manganese oxides rapidly oxidize and return trivalent chromium to solution as hexavalent chromium. In the sediment, oxidation and re-adsorption can transfer chromium (VI) from manganese oxides to iron oxides. Hexavalent chromium in the aqueous phase is sequestered by iron oxides via adsorption when chromium moves across the sediment/water interface. The findings of Ellis (1999) and Icopini et al. (1997, 1998, and 1999) support Takacs' (1988) model of chromium aqueous geochemistry in oxic systems. The two studies find that chromium associates with similar phases (e.g. iron oxides and organic matter). This study will investigate which phase (e.g. iron oxides and organic matter) controls chromium mobility in wetting and drying cycles.

Icopini et al. (1998 and 1999) compared the concentration of chromium in microcosm fluids with the concentration of chromium in the soil. Chromium concentrations in the soil were determined by summing the concentrations of chromium found in the various phases of the soil. The results of this comparison are presented graphically in figure 2. The x-axis of figure 2 is labeled with the six

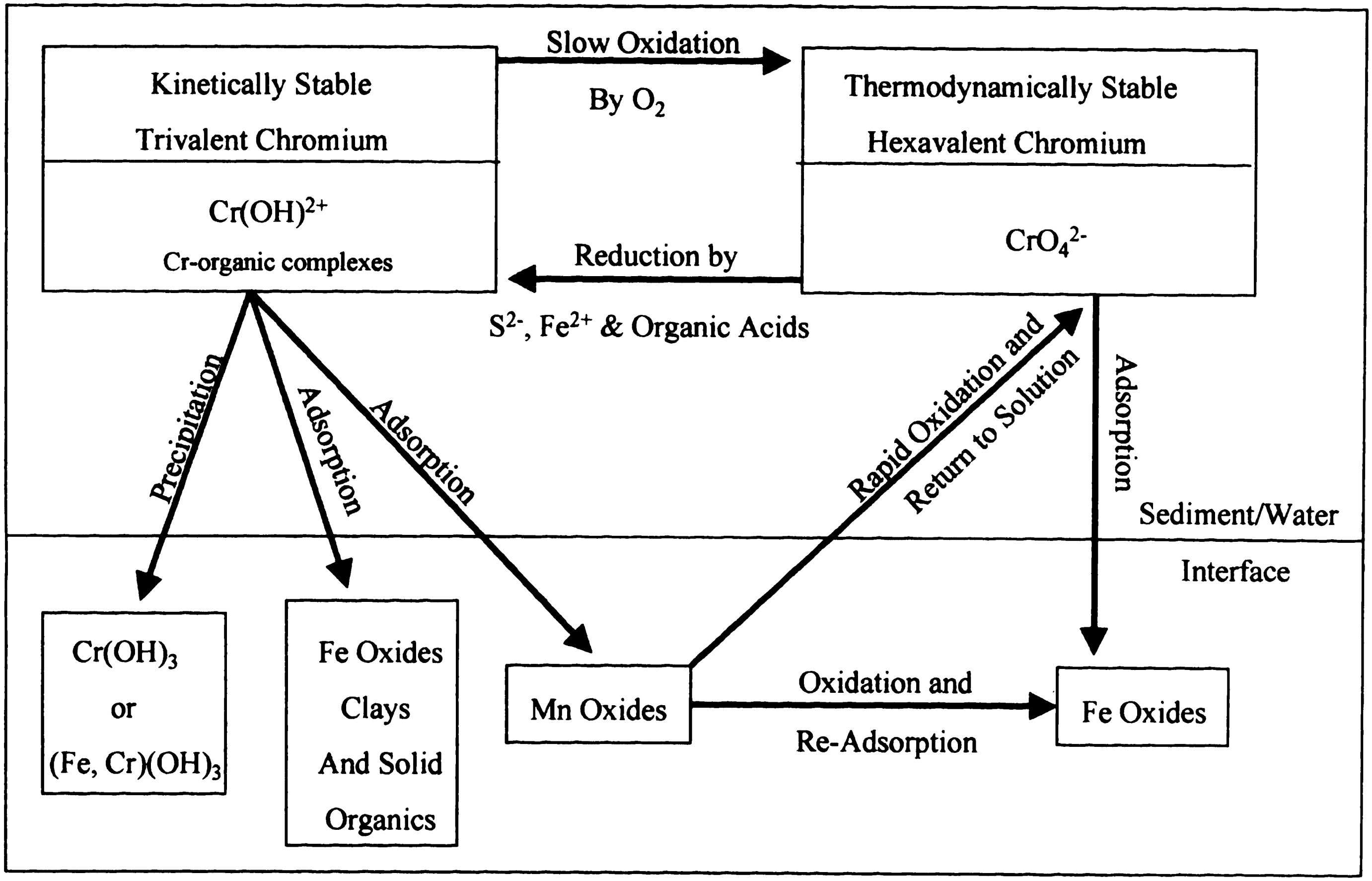


Figure 1: Conceptual Model of Chromium Geochemistry in Oxic Aqueous Systems (Takacs, 1988)

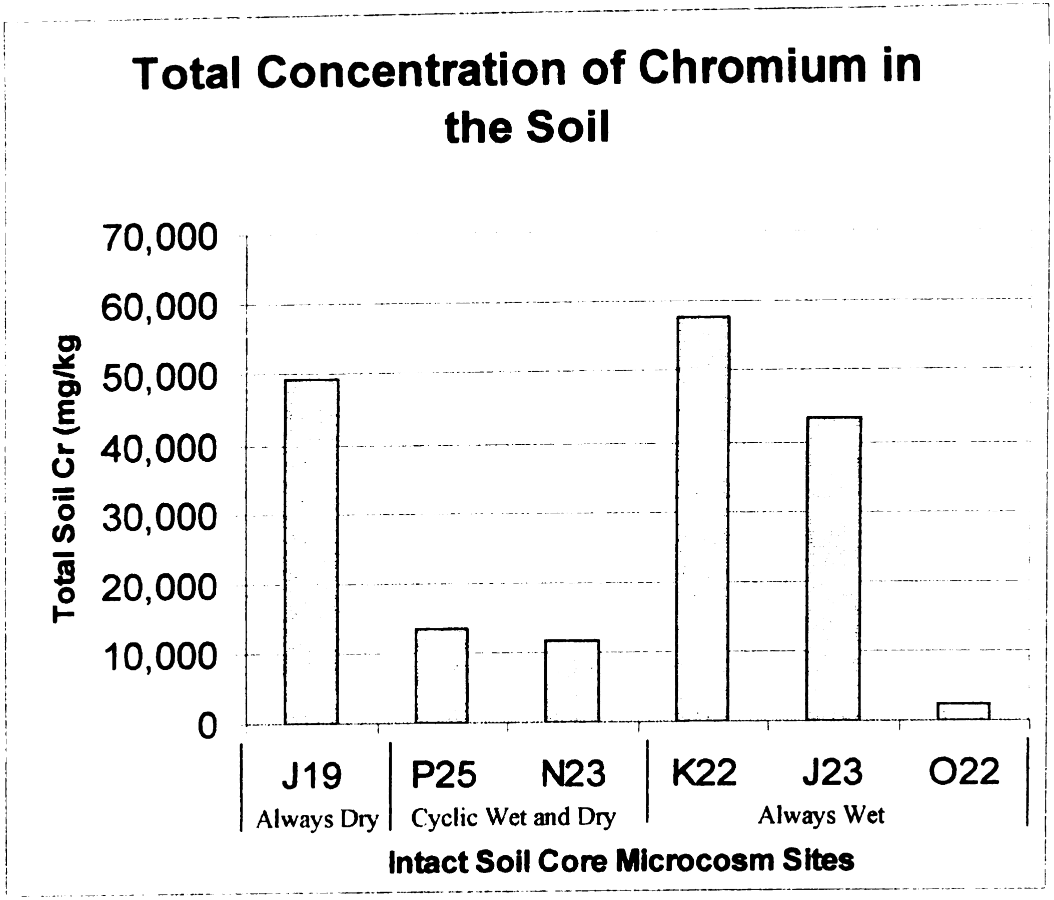


Figure 2: Total concentration of chromium in the soil arranged in order of highest to lowest amount of chromium present in the microcosm exchange water (after Icopini, 1998)

microcosm sites. The sites are arranged left to right in order of highest to lowest amount of chromium present in the microcosm exchange fluid. On the y-axis, the concentration of total chromium in the soil is represented in mg/kg. The highest chromium concentration in the soil was found in sample K22. However, compared to J19, J23, N23, O22, and P25, K22 had a lower chromium concentration in the microcosm exchange fluid than J19, P25, and N23. Thus, the concentration of chromium in the soil (Figure 2) does not determine its concentration in the exchange fluids, which is presented in color in Figure 3.

In addition, Icopini et al. (1998, 1999) assessed the possible factors that could limit chromium mobility from the soil. They utilized an intact soil core microcosm in the laboratory to evaluate the effects of acid rain on metal mobility. Soils used for the microcosm were acquired, using a split spoon corer, from six different locations at the wetland site that represented the different redox conditions and saturation states. Results of the acid rain simulation showed that chromium concentrations in the microcosm solutions were initially high and then decreased over time (Figure 3).

From observations presented by Ellis (1999) and Icopini et al. (1997, 1998, and 1999), the field saturation state of the soils collected for the microcosm experiments can be divided into three categories (always dry, cyclicly wet and dry, and always wet). Site J19 was always dry, sites N23 and P25 were periodically wet and dry; and sites K22, J23, and O22 were always wet.

A connection was found between the total concentration of chromium in the soil (Figure 2) and the microcosm exchange fluids from the intact soil core microcosm (Figure 3). The highest concentrations of chromium in the microcosm

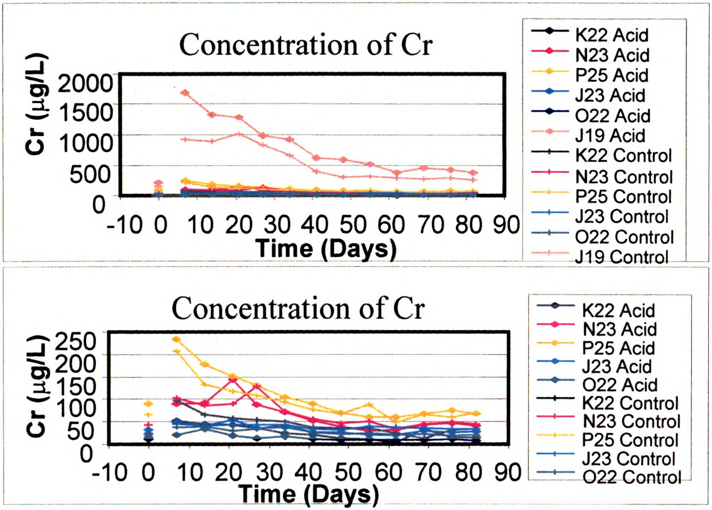


Figure 3: Graphs of chromium concentration vs.time for exchange fluids from the intact soil core microcosm (After Icopini, 1998). Each symbol represents the fluids from a microcosm site.

exchange fluids were associated to the sites whose field saturation state was either always dry or cyclicly wet and dry. There was no correlation found between the total concentration of chromium in the soil with the chromium concentration in the microcosm exchange fluids. When the soils were analyzed using sequential chemical extractions, Icopini et al. (1998) noted that P25 and N23 had lower chromium concentrations than J19, J23, and K22. However, the results from the microcosm exchange fluids showed that the chromium concentrations from P25 and N23 (cyclicly wet and dry sites) were higher than the concentrations from K22, J23 and O22 (always wet sites). These results were interpreted to indicate that soils that were always wet would tend to have the greatest capacity to immobilize chromium, perhaps through the formation of $Cr(OH)_3$ or by sorption on organic matter. On the other hand drying or decreasing the saturation state and then subsequent rewetting may increase chromium mobility.

2.0 Objectives

Field observations by Ellis (1999) and Icopini (1997, 1998, and 1999) noted that some sites would be wet during some observation periods. Additional studies reported that soils from the sites that underwent saturation changes in the field released higher levels of chromium to solution during laboratory leaching studies. The intact soil core microcosm work performed by Icopini et al. (1998 and 1999), showed a possible correlation between the field saturation state of the soil and the ease of metals (e.g. chromium) to mobilize. The field observations and laboratory results from the intact soil core microcosm led to the questions that are the focus of this research.

The objective of this thesis is to address the role of wetting and drying on chromium mobility. The mechanisms of chromium mobility will be evaluated by (1) aerobic microbes degrading organic matter releasing chromium to solution, (2) the cycling of iron oxides liberating chromium when the soil is re-wet, and (3) the solubility or detachment of soil particles containing chromium. The questions addressed in this study were (1) is there evidence that wetting and drying enhances chromium mobility? (2) are microbes, through aerobic processes, degrading organic matter and releasing chromium to solution? (3) does the cycling of iron oxides liberate chromium when the soil is re-wet? (4) is solubility or detachment from particles the main mechanism for chromium mobility from soil?

3.0 Approach

Various researchers have investigated the effect of wetting and drying on the biogeochemistry of soils (e.g. nitrogen accumulation and Tc mobility). Haynes and Swift (1989) looked at changes in the accumulation of nitrogen and pH in air-dried soils that had been re-wet. This was done because re-wetting soil results in higher microbial activity which leads to an accumulation of nitrogen in the soil. Eight different non-hydric soils, seven silt-loams and one clay-loam, were used in the experiment to evaluate the influence of wetting and drying on different soil types. Soil samples were dried in a drying cabinet for 48 hours at 22°C. The duration of the experiment was six weeks. At the end of each 48-hour drying period, the soil samples were analyzed for pH, ammonium, microbial activity, and nitrate. Microbial activity was limited in some samples by means of fumigation with chloroform. Two major conclusions were reached from this study. First, concentrations of nitrate and/or ammonium increased after every re-wetting event. Second, the pH of soils was not affected by the microbial community and the processes of re-wetting air-dried soils. Crozier et al. (1995) looked at the production of methane and reduced sulfur gas from dried and re-wet wetland soils and noted that methane production increased upon re-wetting. After re-wetting an increase in available carbon for methane production was also noted which agrees with the work done by Hall and Hall (1996).

Westfall et al. (1973) investigated the effects of wetting and drying on the concentration of aluminum in acidic soils. The soils were dried for seven days at 105°C. The duration of re-wetting period was also seven days. From their research, they noted that aluminum concentrations decreased after one wetting and drying cycle. Furthermore, they concluded that organic matter influences the amount of aluminum that can be extracted from soils. Haynes and Swift (1991) looked at the change in the mobility of Cu, Zn, Fe, and Mn in soils that were both air-dried and oven-dried and then re-wet. The air-dried soils were maintained in a 22°C cabinet that had air circulation for a 48-hour period. The oven-dried soils were maintained at 100°C for 48 hours. Sequential extractions were performed on the air dried, and oven dried soils. Soil samples were re-wet on weeks one, two, four, and eight of the experiment. Haynes and Swift (1991) noted that the mobility of Cu and Zn increased following the drying. From the sequential chemical extractions, Cu and Zn concentrations decreased in the soil after drying. Tagami and Uchida (1996) evaluated the mobility of Tc in waterlogged soils from rice paddy fields. Tc (VII) is the most mobile and plant available form of Tc which is a contaminant from nuclear weapons and power facilities. The soils were air-dried, sieved and then saturated and analyzed. Tagami and Uchida (1996) concluded that under saturated conditions, Eh values are low indicating reducing conditions, and Tc (VII) was transformed to Tc (IV) by the microorganisms in the soil. Thus under reducing conditions, the availability of Tc to plants is lowered. Tagami and Uchida (1999) continued their work on the rice paddy soils. In the next set of experiments, they kept the soils at 5°C before use. The soils were then waterlogged and kept in a dark room for 52 days. The soils were then sampled at day 1, 5, 14, 30, and 52 using selective and sequential extraction methods. They also performed an air-drying experiment on the waterlogged soil. Tagami and Uchida (1999) concluded that once Tc (VII) was transformed to its less mobile forms such as TcO_2, TcS_2, or organically bound Tc via microbial processes, Tc would not re-mobilize under wetting and drying cycles.

A generalized conclusion is that wetting and drying does have an impact on the concentration of metals in the soil (e.g. Cu, Zn, Al, Tc). From these studies it was shown that wetting and drying released Cu, Zn (Haynes and Swift, 1991) and Tc (Tagami and Uchida, 1996). However, the studies varied in their approach and execution (e.g. type of soil, drying techniques, drying/wetting periods). The variability of experimental parameters makes it difficult to compare these studies.

To assess the role of microbes in chromium mobility as it pertains to wetting and drying, sterilizing agents were used to kill the microbes during every wetting/drying interval. Past wetting and drying experiments have used chloroform and autoclaving as sterilizers. Sterilizers have been evaluated for their effectiveness in killing certain classes of microorganisms (O'Leary, 1989). Haynes and Swift (1989, 1991) used chloroform. Chloroform is a bacterialcidal agent, but is not effective against spore formers. Alef and Nannipieri (1995) concluded that chloroform might not be appropriate for element mobility studies because chloroform accelerates the decomposition of soil organic matter. Jenkinson and Powlson (1976) concluded that fumigation destroys the fine structure of the soil. Tagami and Uchida (1996) autoclaved the soils to inhibit microbial activity. Autoclaving is a procedure that uses steam under pressure destroying the structure of the soil, and liberating high concentrations of organic substances (Alef and Nannipieri, 1995).

Another method for sterilization is applying a liquid sterilizer. Formaldehyde and glutaraldehyde are effective against all bacteria, viruses, fungi, and spore formers (O'Leary, 1989).

Previous studies on wetting and drying were used as a guide in the design of this study. For this project the methods were evaluated from the previous studies and were modified to fit our objectives.

- Previous studies only examined the solid phase (Haynes and Swift, 1989; Crozier et al., 1995; Hall and Hall, 1996; Westfall et al., 1973; Haynes and Swift, 1991; Tagami and Uchida, 1996; and Tagami and Uchida, 1999). This study evaluated metals in the aqueous phase because the aqueous phase is more sensitive to subtle changes in the mobility of chromium.

- The duration of the experiment was expanded to evaluate the effects of wetting and drying over a longer period of time. Other scientists ended their studies at 52 days. This study continued for 90 days.
- Of the previous studies, only one, Tagami and Uchida (1999), studied what happened when a soil remained saturated for the duration of the experiment. The continually saturated study was expanded to both hydric and non-hydric soils in this study.
- Testing both hydric and non-hydric soils allows us to investigate the role of organic matter in chromium mobility during wetting and drying cycles.
- An air-dried approach was used in this project because room temperature falls within the environmental range of temperatures at the field site. In addition, using oven dried soils would impact the soil structure differently than drying soils within the normal environmental range of temperatures for the wetland site.
- Release of chromium from organic matter by degradation induced by aerobic microbes is evaluated. Other studies used a fumigant or a physical process to kill the microbes in the soil. In this study formaldehyde and glutaraldehyde, which are both chemical sterilizers, were used to kill microbes.
- Research has been presented on the importance of wetting and drying for several elements including Tc, Cu, Zn, Fe, and Mn. For this study, the mobility of several elements was investigated. The elements of interest were chromium, iron, manganese, and strontium. These elements were selected for their concentrations and environmental behavior. Chromium and strontium have not been studied before in the context of wetting and drying.

THIS STUDY

As was illustrated in the early discussion on wetting and drying of soils, research groups have performed wetting and drying experiments to ascertain a variety of parameters including mobility of metals at room temperature or at higher temperatures using an oven. An oven was not used in this study because the fine structure of the soil would be damaged thereby restricting the evaluation of the microbial activity on metal mobility. For this study, the soils were dried at room temperature. This was done because room temperature falls within the normal environmental range of temperatures found at the wetland site. The air temperature at the site can range from below 0°C to a high around 30°C; therefore, using a drying cabinet at 22°C is within the normal temperature range at the site. Four aspects of this experiment are presented in this section.

The first aspect to be evaluated is the analysis of the liquid phase. Previous works (Westfall et al., 1973; Crozier et al., 1995; Hall and Hall, 1996; Haynes and Swift, 1991; and Tagami and Uchida, 1999) analyzed the solid phase in their experiments. Using the liquid phase in this study allows us to observe/examine small-scale variations and elements of low concentration. The instrument used to analyze the liquid filtrate was the Micromass Platform Inductively Coupled Plasma Mass Spectrometer with a hexapole collision cell (ICP-HEX-MS) where concentrations can be quantified in the ng/L range. In addition to the liquid phase, the solid phase was evaluated using concentrated nitric acid extractions.

A second aspect investigated was the microbial inhibitors used in the experiment. In this study, the chemicals used for sterilization were formaldehyde and glutaraldehyde. Neither formaldehyde nor glutaraldehyde had been used in previous wetting and drying studies (Haynes and Swift, 1991and Tagami and Uchida, 1999). Formaldehyde and glutaraldehyde were selected on the basis of their ability to kill microbes without disturbing the texture of the soil.

Another aspect of this experiment was the duration of the experiments. The first experiment (weekly and bimonthly drying treatments) lasted for six months, and the second experiment (DDAW, formaldehyde, glutaraldehyde, and always wet treatments) lasted for three months. Of the previous wetting and drying studies the longest duration of a wetting and drying experiment was 52 days by Tagami and Uchida (1999). The longer duration of the experiment allowed for an evaluation of the effects of wetting and drying over time.

Previous studies concentrated on one or two elements. Multi-element analysis using the Micromass Platform ICP-HEX-MS allows for comparisons between a host of redox sensitive and non-redox sensitive elements. The complete list of elements analyzed is presented in the methods section. For this study, the elements of particular interest were chromium, iron, manganese, and strontium. Each was selected for unique geochemical characteristics that could be used in evaluating the controlling factors of chromium mobility. Chromium (III) and (VI) are the two dominant valence states for chromium in the environment where chromium (VI) is the more toxic and mobile (Bartlet and James, 1979 and Hem, 1985). At the wetland site, the dominant form of chromium is chromium (III) (Ellis, 1999). In soils, chromium favors the chromium (III) valence state and complexes with organic matter (McBride, 1994). In addition to chromium's tendency to complex with organic matter, chromium will substitute for iron and form an insoluble precipitate $Cr(OH)_3$. Mechanisms that may induce chromium to liberate from the soil need to be evaluated. Iron and manganese were selected for being elements that undergo oxidation-reduction and for their sequestering of chromium to iron and manganese oxy-hydroxides (Ellis, 1999). Manganese complexes with carbonates and oxides not associated with chromium, but it is a redox sensitive element (Hem, 1985 and McBride, 1994). Manganese oxides convert Cr (III), the less toxic state, to Cr (VI), the toxic state. Iron is important to study because Fe-oxides commonly sequester chromium. Finally, strontium was selected because it is not an oxidation/reduction sensitive element. Strontium represents the entire class of redox independent elements. Strontium is commonly found in carbonates, and its concentration is controlled by carbonate solubility. Strontium can replace calcium in carbonate minerals due to similar chemical characteristics (Hem, 1985).

Images in this thesis are presented in color.

SITE DESCRIPTION

The site of investigation is a former tannery in Northern Michigan that operated from the early 1900's to 1958. A wetland area is adjacent to the waste disposal site for the tannery (Ellis, 1999). The wetland area is a classified as a mix of unconsolidated bottom, forested, and scrub-shrub wetlands (Cowardin et al., 1979). The sampling grid used is presented in Figure 4, and soil types present at the site are represented in Figure 5. Six locations were chosen for this study. These locations were the same sites used in the intact soil core microcosm experiments done by Icopini (1998, 1999).

The six sites selected for investigation were J19 (0-0.5 feet), J23 (0-0.5 feet), K22 (0-0.5 feet), N23 (0-0.5 feet), O22 (3-3.5 feet), and P25 (0-0.5 feet). The sites are characterized further by pH, percent soil organic matter, iron concentration, chromium concentration, saturation state, and depths in Table 1. Site J19 is always dry, contains a high percentage of organic matter, and has relatively high chromium concentrations. Sites N23 and P25 exhibit cyclic wet and dry conditions in the field, contain a high percentage of organic matter, and have relatively high chromium concentrations. Sites J23 and K22 are continuously water saturated in the field, contain a high percentage of organic matter, and have relatively high chromium concentrations. Site O22 is always water saturated, contains a low percentage of organic matter, and has relatively low chromium concentrations.

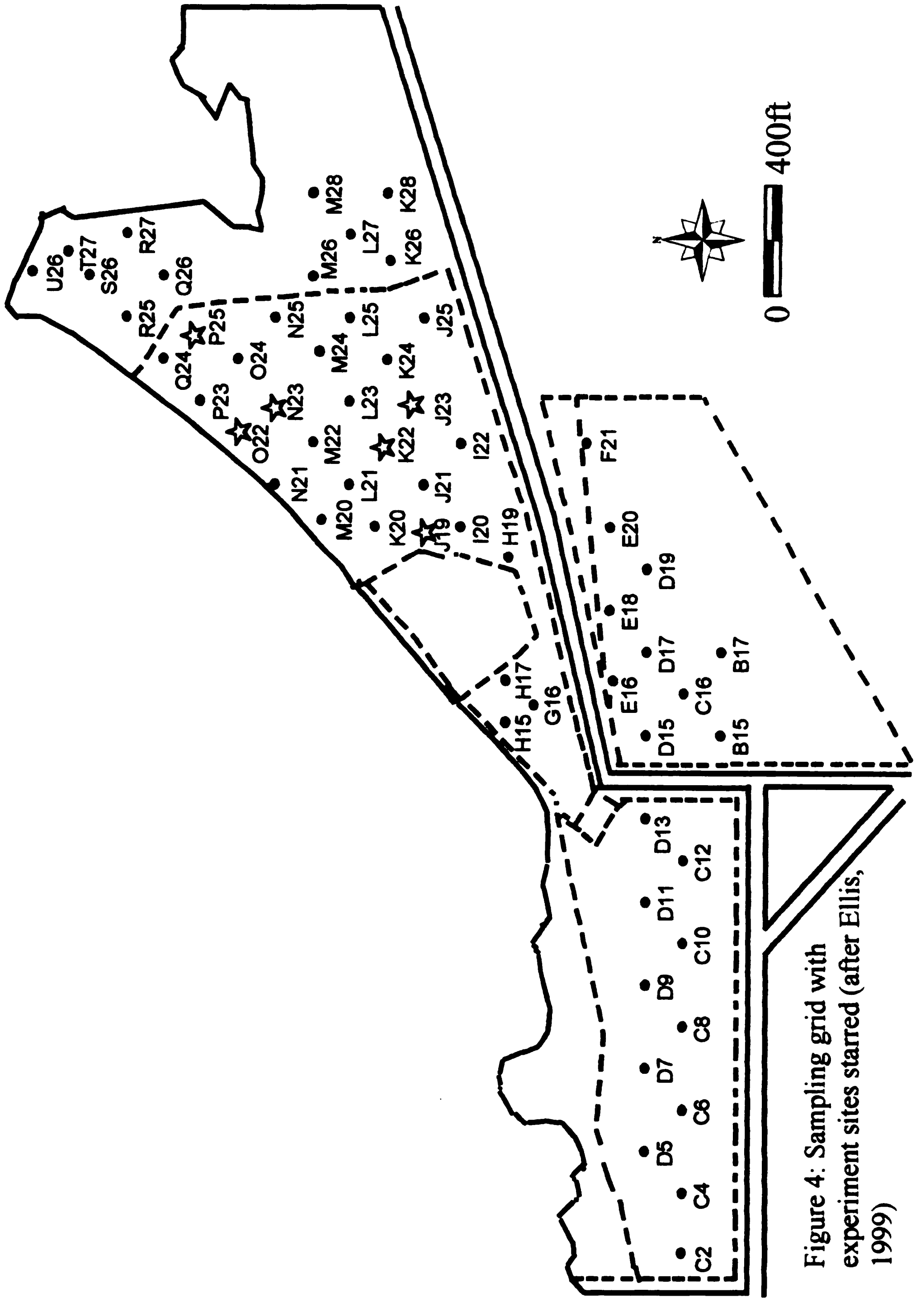


Figure 4: Sampling grid with experiment sites starred (after Ellis, 1999)

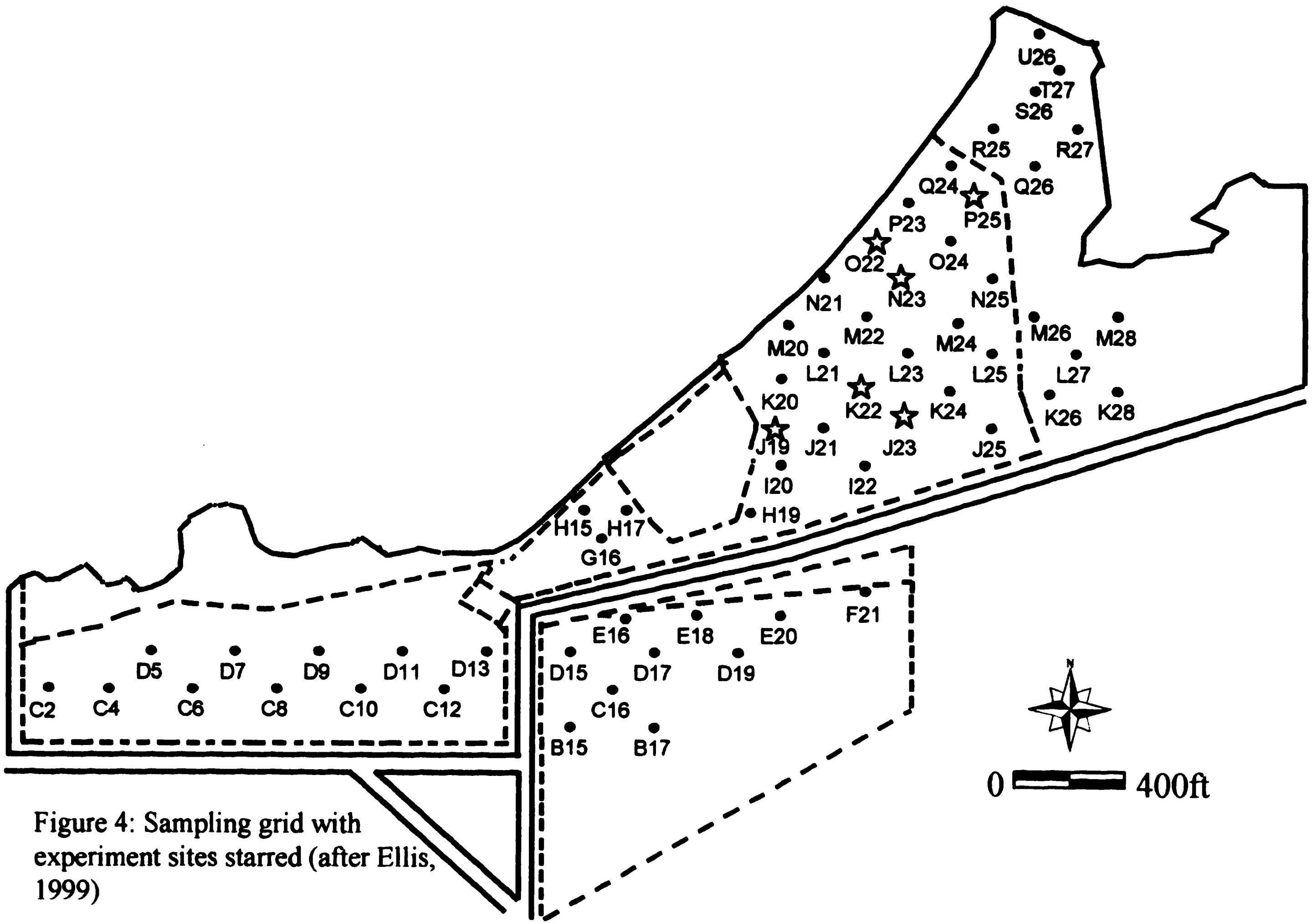


Figure 4: Sampling grid with experiment sites starred (after Ellis, 1999)

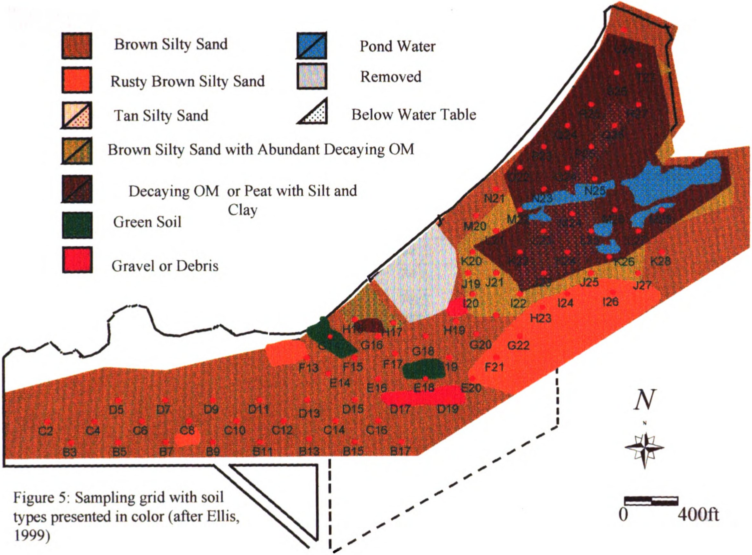


Figure 5: Sampling grid with soil types presented in color (after Ellis, 1999)

Table 1: Microcosm Site Characterization after Icopini et al. (1997, 1998, and 1999) and Ellis (1999)

Site	Depth (ft)	Observed Environment	Soil Organic Matter (%)	Soil Cr (mg/kg)	Soil Fe (mg/kg)	Porewater pH
J19	0-0.5	dry	65	49,209	9,704	NA
N23	0-0.5	cyclic wetting & drying	77.3	11,659	7,278	6.45
P25	0-0.5	cyclic wetting & drying	62.1	13,552	5,348	6.61
J23	0-0.5	running water	74.8	43,127	1,252	6.65
K22	0-0.5	standing water	76.5	57,584	44,295	6.91
O22	3-3.5	always wet	4.5	2,408	2,765	7.11

METHODS

1.0 Sample Collection

Soil samples were collected on October 12, 1998, and were taken from the same depths as the samples collected for the microcosm experiments performed by Icopini et al. (1997, 1998, and 1999) and Ellis (1999). The samples collected from 0-0.5 feet depth were scooped using a clean plastic cup. The sites sampled at this shallow depth were J19, J23, K22, N23, and P25. Sediment at each site was homogenized using a plastic bucket and transferred into nine separate plastic urinalysis cups. Each cup held approximately 250 grams of saturated sediment. A hand corer was used to excavate a hole to a depth of 3-3.5 feet to collect the samples at site O22. The sediment from O22 was homogenized in a plastic bucket and separated into nine plastic cups. The 54 cups of sediment were stored on dry ice for transport back to the laboratory, where they were placed in a freezer until the experiments were carried out.

2.0 Drying Cabinet Design

A cabinet was designed for the experiments to house the drying vessels and to circulate filtered air that would come in contact with the soils. The drying cabinet was a Rubbermaid^{TM} 33.5 x 21 x 10.8 inch jumbo clear plastic box with a removable snap on lid. Two holes were cut at one end of the cabinet. A sterile plastic filter cup made by Corning containing a 0.45 μm filter was inserted into one of the holes. The filter cup had a plastic attachment where a vacuum could be attached to pull air through the filter. A fan was placed in front of the filter cup cap to circulate air throughout the cabinet. A hose was placed through a second hole in the cabinet and attached to a second vacuum to remove the filtered, excess air out of the box.

3.0 Sample Preparation

The samples were thawed and placed in a glove bag filled with nitrogen. The nine plastic cups for each site were combined and homogenized in a bucket inside the glove bag. Centrifuge tubes and watch glasses used for the wetting and drying experiments and for total extractions were weighed using a scale inside the glove bag. Exactly fifteen grams of homogenized sample were then separated into 50-milliliter centrifuge tubes for the experiments. Since 30 milliliters of water were necessary for experiments, 15 grams of saturated soil was the maximum amount of soil that could be placed in the centrifuge tube. Six to ten grams of saturated soil were weighed on watch glasses for total extractions (Appendix I).

4.0 Total Extractions

Three splits from each homogenized sample were analyzed for the nitric acid extractable concentration of metals in the soil using the method after Hewitt and Reynolds (1990) presented in Appendix II. Wet sediment was placed on the watch glasses and dried in an oven at 50°C for approximately 24 hours. The oven-dried sediments were ground into a fine powder using a ceramic mortar and pestle. One half gram of sediment was placed into a CEM MDS 81D Teflon digestion vessel. For each set of twelve samples a blank and a standard reference material (Buffalo

River Sediment SRM 2704) were digested. The blank consisted of ten milliliters of concentrated HNO_3 added to the Teflon digestion vessel.

The vessels were then placed in the CEM MDS 81D microwave. The pressure monitor was connected to the vessel that contained the sample with the highest amount of organic matter. The samples with the highest organic matter were listed in Table 7, 8, and 9 found in Ellis (1999). The microwave was set for 15 minutes at 100% power, followed by a cool down period of 0% power for 20 minutes. The vessels remained in the microwave until they reached a pressure of less than 20 psi, at this point they were removed from the microwave. Under a fume hood, the vessels were then disassembled and 90 milliliters of distilled deionized water were added to each vessel. The samples were filtered through a 0.4 µm acid washed Nucleopore filter into acid washed 60 milliliter bottles. The filtrate was analyzed for total metal concentrations on an inductively coupled plasma-hexapole-mass spectrometer (Micromass Platform ICP-HEX-MS).

5.0 Duration of Drying Treatment (weekly and bimonthly drying)

For six months, samples underwent a wetting and drying procedure. Fifty-milliliter centrifuge tubes containing exactly fifteen grams of sediment were used for this experiment. The experiment was designed to assess the effect of two different drying intervals (one week and bi-monthly) had on the release of metals from wetland soils. Before starting the experiment the soils were initially saturated. Thirty milliliters of distilled, deionized, autoclaved water were added to each centrifuge tube and allowed to sit in the centrifuge tube for three hours. The supernatant water was removed from each vessel using a 30-milliliter syringe. The supernatant water was filtered using an acid washed Nucleopore 0.4 μm filter, and the filtrate was split into two separate acid washed bottles and three couvets. Five milliliters of filtrate were collected for dissolved organic carbon analysis. Eight and a half milliliters of filtrate were added to couvets for Cr (VI) and Fe (II) analysis. Remaining filtrate was acidified with optima HNO_3 to a pH of less than two and analyzed for cations. After the filtrate was removed the centrifuge tubes with the sediment were placed inside the drying cabinet. Each centrifuge tube was covered with a filter to filter air that would come in contact with the soil. Centrifuge tubes remained in the cabinet for their respective drying intervals and removed from the cabinet at the appropriate time. Samples were again saturated using 30 milliliters of distilled, deionized, autoclaved water and sampled the same as the initial saturation event. These steps were repeated for six months.

6.0 Chemical Sterilizer Treatments (formaldehyde and glutaraldehyde) and Distilled Deionized Autoclaved Water Treatment

Chemical sterilizer treatments compared to the DDAW (distilled, deionized, autoclaved water) treatment was used to assess the role of microorganisms in releasing metals to the environment. Three sets of centrifuge tubes containing fifteen grams of sediment were separated into three categories: DDAW treatment, formaldehyde treatment, and glutaraldehyde treatment. The three sets of soils underwent the same wetting and drying procedure, only varying in the treatment solution used to saturate the soils. The DDAW solution consisted of distilled, deionized, autoclaved water. The formaldehyde treatment solution was an 8% formaldehyde solution made with distilled, deionized, autoclaved water. The glutaraldehyde treatment solution was a 2% glutaraldehyde solution made with distilled, deionized, autoclaved water (O'Leary 1989). The soils in the centrifuge tubes were first saturated for three hours with 30 milliliters of their respective treatment solution for an initial (time zero) evaluation). The treatment solutions were removed from the centrifuge tubes and filtered. The filtrate was analyzed for cations, dissolved organic matter, Cr (VI), and Fe (II). The centrifuge tubes were placed uncapped in the drying cabinet for fifteen days. After fifteen days, the soil samples were saturated again for three hours using the treatment solutions, and the same analysis was done as in the time zero saturation. The pH of the samples was analyzed at two saturation events. The experiment continued for three months.

7.0 Always Wet Treatment

The other experiment that was conducted was an always wet treatment. This treatment was conducted simultaneously with the chemical sterilizer treatment; therefore, the DDAW treatment was compared to the always wet treatment. For this treatment, the same parameters were evaluated for the extracted solution. Soil in the centrifuge tubes remained saturated throughout the three-month duration of the experiment. Thirty milliliters of distilled, deionized, autoclaved water were added to each centrifuge tube. The centrifuge tube was capped and placed into the drying cabinet for fifteen days. After fifteen days, the remaining water was removed and filtered. The filtrate was analyzed for cations, dissolved organic carbon, Cr (VI), and

Fe (II) and used as the starting concentration. After the remaining water was extracted, thirty more milliliters of distilled, deionized, autoclaved water were added to the centrifuge tube. This water was allowed to sit in the centrifuge tube for three hours. After three hours, the water was removed from the centrifuge tube and filtered using an acid washed 0.4 μm filter. The filtrate was analyzed for cations, dissolved organic carbon, Cr (VI), and Fe (II). The pH of the water was analyzed for two saturation events. The sample was then re-saturated, re-capped, and placed back into the drying cabinet. This experiment continued for three months.

8.0 Spectrophotometric Methods

Cr (VI)

Hexavalent chromium was analyzed using a Spectronic Spec 20d at a wavelength of 540 nm. A solution of 0.3 mL of 1.2 M H_2SO_4 and 0.15 mL of diphenylcarbazide solution were added to 3.0 mL of filtrate. The 1.2 M H_2SO_4 is made by slowly adding 6.5 mL concentrated H_2SO_4 to DDW and diluting to 100 mL. The 0.15 mL of diphenylcarbazide is made by dissolving 0.2 grams of diphenylcarbazide and 1.0 grams of phthalic anhydride in 200 mL of ethanol (AWWA, 1971).

Fe (II)

Ferrous iron (Fe II) was analyzed using a Spectronic Spec 20d at a wavelength of 508 nm. A solution of 100 μL of trace metal grade HCl, 1.0 mL of phenanthroline, and 0.5 mL of ammonium acetate were added to 2.5 mL of filtrate (AWWA, 1971).

9.0 Dissolved Organic Carbon Analysis

Samples for dissolved organic carbon were analyzed on a Shimadzu TOC 5000A: Organic Carbon Analyzer. Details of this method are presented in Appendix II. The TOC analyzer requires two solutions for calibration when analyzing for organic carbon. The first solution is an inorganic carbon solution. The inorganic carbon (IC) solution was prepared by dissolving 3.5 grams of sodium hydrogen carbonate and 4.1 grams of sodium carbonate into one liter of E-pure water. The organic carbon (OC) solution was prepared by dissolving 2.125 grams of reagent grade potassium hydrogen phthalate in one liter of E-pure water. Samples were diluted one to one for analysis prior to analysis.

The carrier gas (ultra zero pure air) is set at 4-5 Kg/cm, and the gas flow is 150 mL/min. The furnace must warm up for approximately one hour to 680°C. Before running samples the IC reagent (25% phosphoric acid) and the glass humidifier bottle need to be checked to make sure they are properly filled. A calibration is done using both IC (Inorganic carbon) and OC (organic carbon).

10.0 ICP-HEX-MS

The concentrations of metals were measured using a Platform Inductively Coupled Plasma Mass Spectrophotometer with a hexapole collision cell from Micromass (ICP-HEX-MS). The elements analyzed on the ICP-HEX-MS were

^{59}Co, ^{60}Ni, ^{63}Cu, ^{51}V, ^{114}Cd, ^{208}Pb, ^{75}As, ^{47}Ti, ^{45}Sc, ^{66}Zn, ^{88}Sr, ^{80}Se, ^{27}Al, ^{52}Cr, ^{138}Ba, ^{44}Ca, ^{54}Fe, ^{56}Fe, ^{24}Mg, and ^{55}Mn. Of these elements, only a few will be discussed in this thesis: ^{52}Cr, ^{56}Fe, ^{55}Mn, and ^{88}Sr. Chromium is the objective of the study and selected because of its abundance at the wetland site. Iron and Manganese were selected because they are associated with chromium cycling and are sensitive to changes in redox conditions. Strontium was selected because it is not affected by variations in the redox conditions. Complete results are presented in Appendix III.

Elements were divided into groups based on their expected aqueous concentrations: low concentration group ^{59}Co, ^{60}Ni, ^{63}Cu, ^{51}V, ^{114}Cd, ^{208}Pb, ^{75}As, ^{47}Ti, and ^{45}Sc; intermediate concentration group ^{66}Zn, ^{88}Sr, ^{80}Se, and ^{27}Al; and high concentration group ^{52}Cr, ^{138}Ba, ^{44}Ca, ^{54}Fe, ^{56}Fe, ^{24}Mg, and ^{55}Mn. Multi-element standards were used to calibrate the ICP-HEX-MS analyses. The method for standard preparation is presented in Appendix IV. NIST 1643d was analyzed during every run as an aqueous standard reference material (SRM). A run consists of approximately 120 samples, blanks, standards, and SRMs. All solutions were combined with a one-milliliter of a solution that contained 20 μg/L of indium and bismuth, which were used as internal standards. A concentric nebulizer and an autosampler (Cetac ASX-500) were used during the analyses. The concentrations of the different analytes in the aqueous solutions are reported in μg/L. Digested soil samples were diluted one to one hundred for analysis on the ICP-HEX-MS allowing their concentration to be in the range of the detector. Data was collected using single ion recording mode (peak jumping).

RESULTS AND DISCUSSION

In this section of the thesis, the results of the experiments will be summarized, discussed, and interpreted. Four questions were investigated. (1) Does wetting and drying of sediment increase chromium mobility? (2) Does the duration of drying affect chromium mobility? (3) Do aerobic microbes play a role in chromium mobilization during wetting and drying? (4) How does chromium behavior compare to other elements? The data tables are located in appendix V.

1.0 Does wetting and drying of sediment increase chromium mobility?

There is a definite link between wetting and drying of sediment and chromium mobility. Aqueous chromium concentrations were greater in samples that underwent wetting and drying (DDAW treatment) as opposed to samples that remained saturated (always wet treatment). The two treatments differed only by the duration of time that the sample remained saturated. Comparing results from the always wet treatment and the distilled deionized autoclaved water (DDAW) treatment illustrates the influence of wetting and drying of sediment on chromium mobility.

Chromium concentrations are compared between individual samples and between treatments. The results are summarized in Table 2. Table 2 shows a comparison of chromium concentration trends for the DDAW treatment and the always wet treatment. The general trend for the DDAW samples was continually increasing. The only site that did not exhibit a continual increase was O22 where the general trend was a decrease followed by an increase. The percent of change for the

Table 2: Aqueous results for chromium for the four treatments DDAW, Formaldehyde (F), Glutaraldehyde (G), Always Wet (AW), and Bimonthly (BM) for the Sample Locations

	J19	N23	P25	J23	K22	O22
DDAW	Continually increasing	Continually increasing	Continually increasing	Continually increasing	Continually increasing	Decrease followed by increase
F	Continually decreasing	One peak	One, broad peak	Decrease followed by increase	One, broad peak	Decrease
G	Step increasing	Step increasing	Step increasing	Decrease to steady state	Step Increase	Decrease to steady state
AW	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing
BM	Sharp peak with return to initial conditions	Two peaks	One, broad peak	Broad peak decrease to steady state	Sharp peak with return to initial conditions	Decrease to steady state

DDAW samples ranged between a 96% increase for J19 to a 1373% increase for N23. In the always wet treatment, the general trends for all the samples was a continual decrease. All of the samples experienced some degree of decrease. Overall the greatest decrease was found in the samples from site J19 where the percent decrease was 77%. The smallest amount of decrease was found in samples from site K22 where the percent decrease was 34%. From the general trends and the percent of increase and decrease, it is evident that cyclic wetting and drying affects chromium mobility.

In comparing the DDAW treatment and the always wet treatment graphs presented in Figure 6 and Figure 7 respectively, evidence of the impact of wetting and drying can be seen. Chromium concentrations increased over time in the DDAW treatment (Figure 6). Conversely, chromium concentrations decreased over time in the always wet treatment (Figure 7). In addition to the trends being different, maximum chromium concentrations in the graphs for the DDAW treatment (Figure 6) are higher than the maximum chromium concentrations in the graphs for the always wet treatment (Figure 7). Furthermore, the results from the always wet treatment are similar to the intact soil core microcosm results (Figure 3) where chromium concentrations decrease over time (Icopini et al. 1997, 1998, and 1999). This illustrates that wetting and drying influenced chromium concentrations in solution.

In summation, the differences between the two treatments (DDAW and always wet) illustrate the impact that wetting and drying has on chromium mobility. When samples underwent changes in their saturation state, the chromium found in

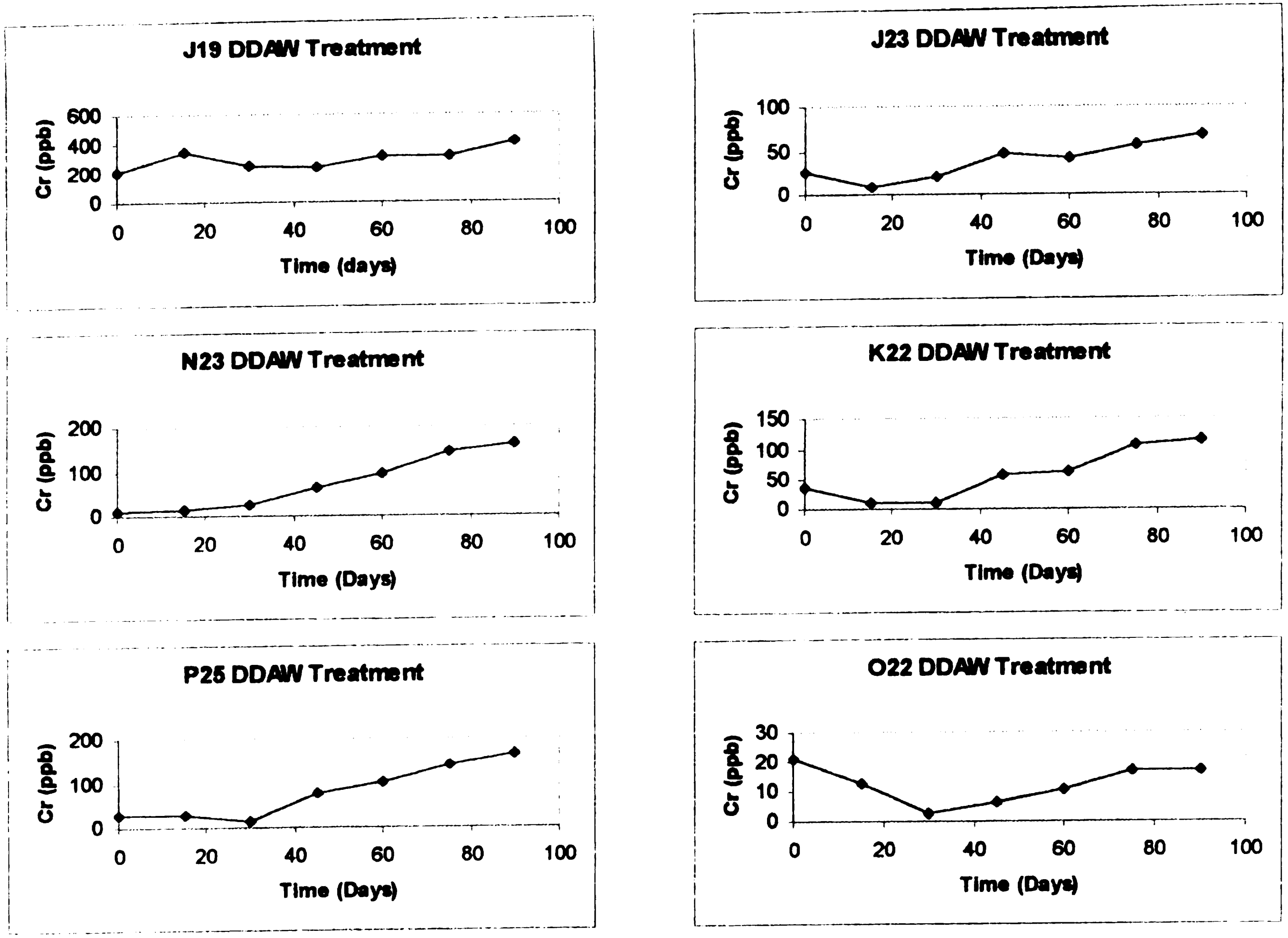


Figure 6: Chromium vs time for DDAW (Distilled Deionized Autoclaved Water) Treatment

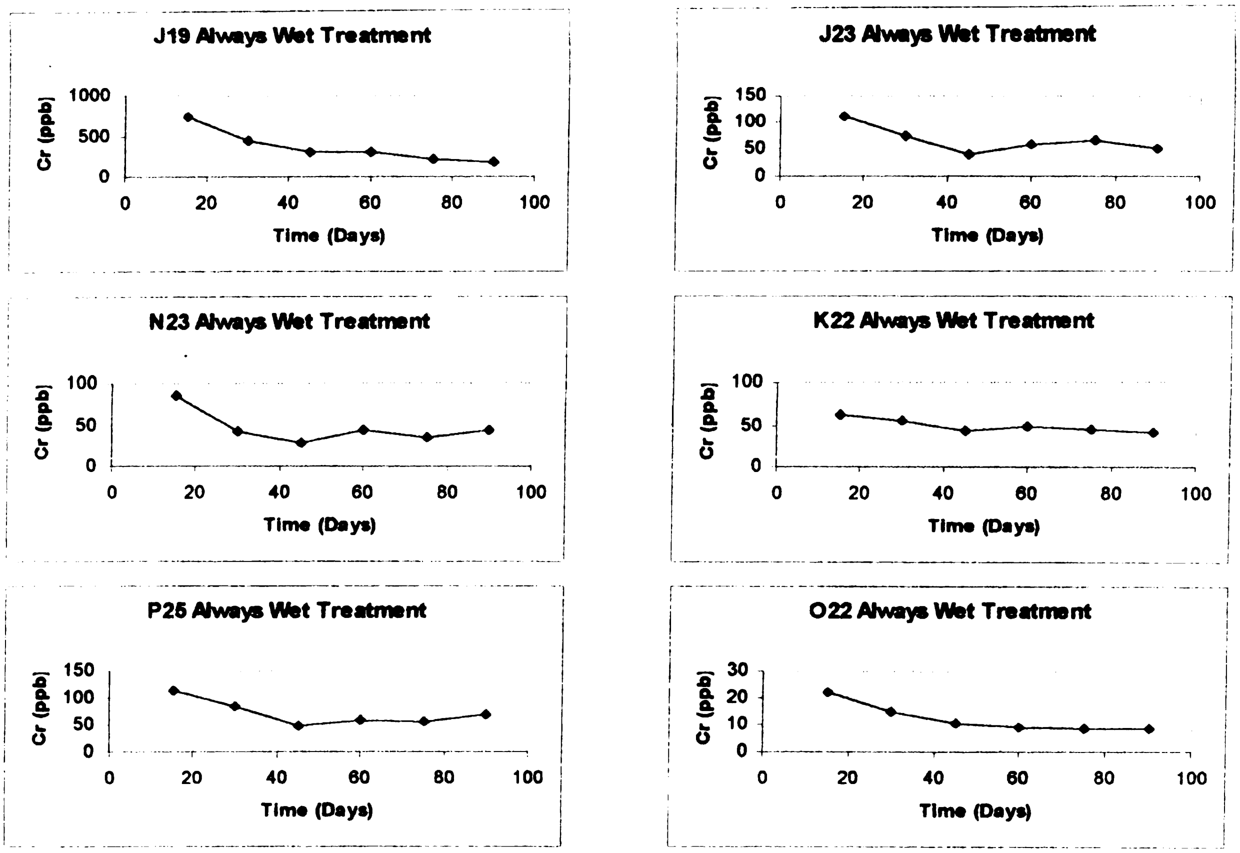


Figure 7: Chromium vs.time for always wet treatment

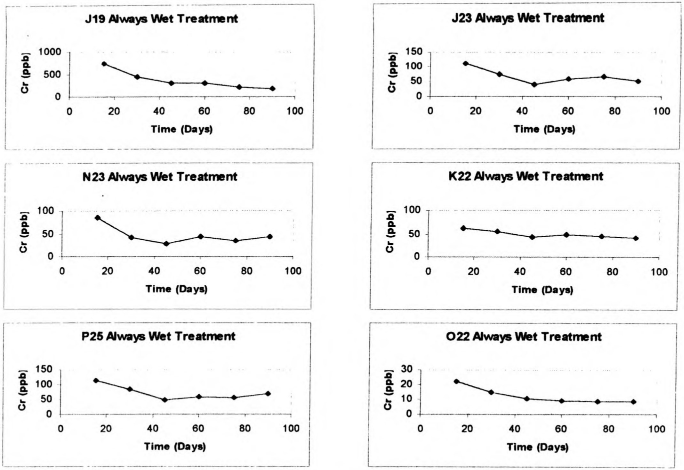


Figure 7: Chromium vs.time for always wet treatment

solution was higher. There are a number of mechanisms that control chromium mobility. Some of the possible mechanisms are the degradation of organic matter by aerobic microbes, cycling of iron oxides, and solubility or detachment from soil particles. This study illustrates that wetting and drying influences chromium mobility, and the amount of chromium released increases over time.

This research supports the findings of Icopini et al, (1997, 1998, and 1999). Increased concentrations of chromium were seen in sites that were cyclicly wet and dry (sites P25 and N23) in the field. The pore water samples collected from the peepers and barrels in the field were higher in P25 and N23 in comparison to J23 and K22 (e.g. always wet sites).

2.0 Does the duration of drying affect chromium mobility?

There is conclusive evidence that the duration of drying affects chromium mobility. The results of the duration of drying experiment for chromium are presented in appendix V.

Concentrations and trends are tied to the field saturation state. When the always dry site J19 was subjected to cyclic wetting and drying conditions it exhibited the highest amount of chromium eluded in the bimonthly drying experiment. Furthermore, the amount of chromium eluded from J19 decreased over the span of the bimonthly experiment, similar to the results of the intact soil core microcosm presented in Icopini et al. (1998). For sites that undergo cyclic wetting and drying in the field (N23 and P25), the concentrations of chromium eluded in the bimonthly drying experiment increased for 60 days and then decreased to a steady state. The general trends for chromium for all the sites studied are located in table 2. After the initial 60 days, the trends were similar to the intact soil core microcosm results. The intact soil core microcosm experiment (Icopini et al., 1998) show a flushing experiment where chromium concentration decreased over time after being continually saturated with a solution (Figure 2). The field saturation state influences the chromium mobility.

The results of the bimonthly treatment experiment cannot be compared to the DDAW experiment. The time that the two samples dried were similar; however, the conditions under which they dried were completely different. The DDAW samples were dried without a filter covering the sample in the drying cabinet while the bimonthly drying samples were covered with a 0.4 μm filter. The filter prevented the complete drying of the samples. The degree of wetness makes a difference. The semi-saturated soils of the drying experiment show similar results to the intact soil core microcosm experiment and the always wet experiment which validates the influence of wetting and drying on chromium mobility.

3.0 Do aerobic microbes play a role in chromium mobilization during wetting and drying?

From research presented by Tagami and Uchida (1996 and 1999) the role of microorganisms in the mobility of chromium was studied. Their results were summarized in the introduction. The role of microbes was evaluated using two different microbial sterilizers formaldehyde and glutaraldehyde. The formaldehyde treatment (Figure 8) and the glutaraldehyde treatment (Figure 9) are compared to the

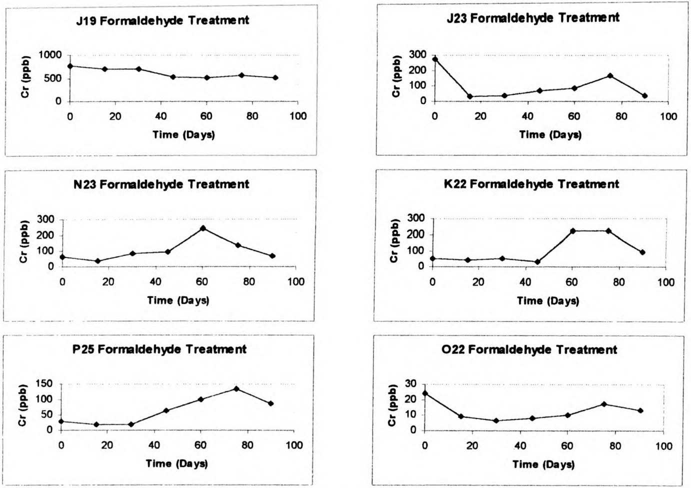


Figure 8: Chromium vs. time for the formaldehyde treatment

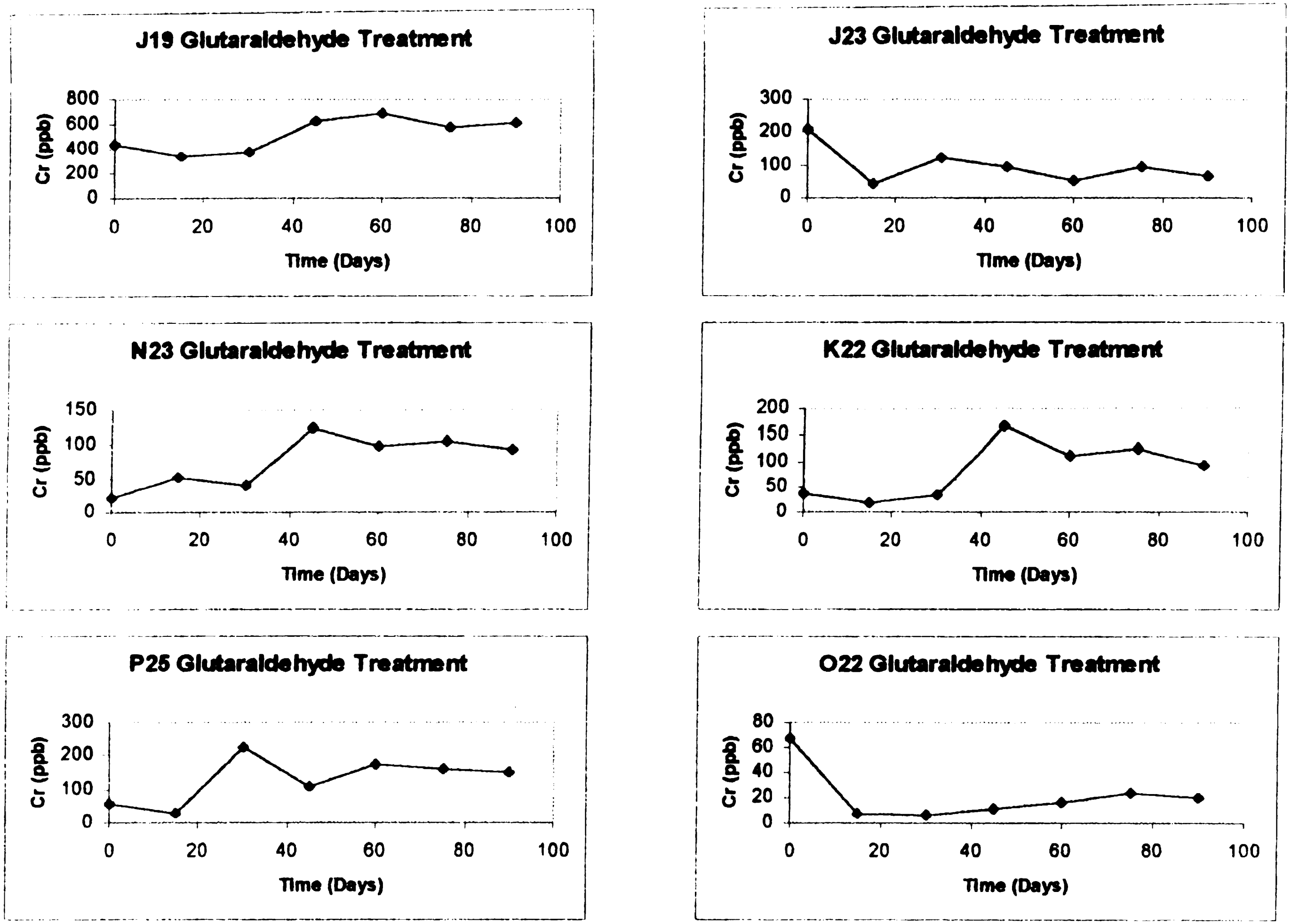


Figure 9: Chromium vs. time for the glutaraldehyde Treatment

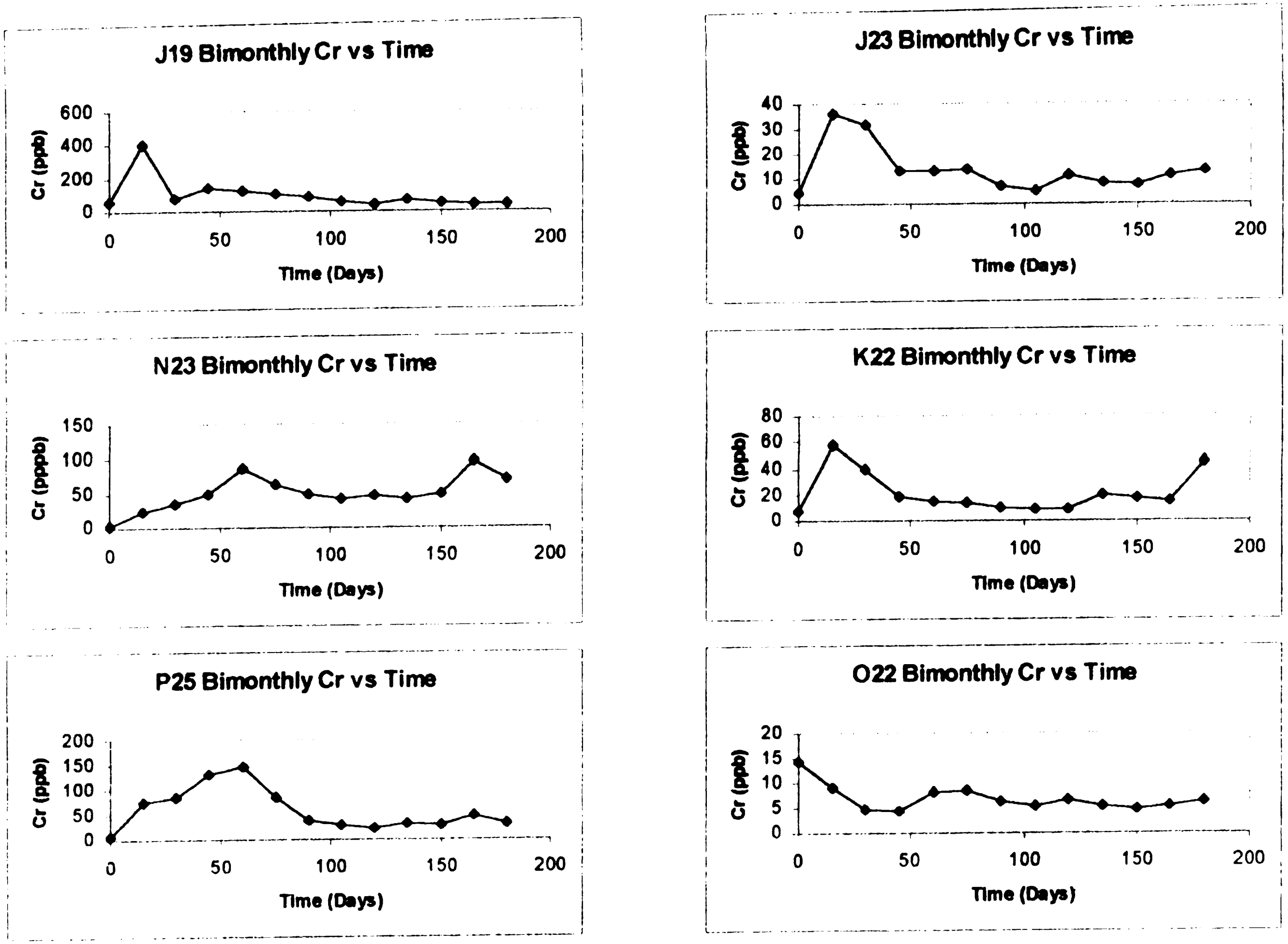


Figure 10: Chromium vs. time for bimonthly treatment

treatment where microbes were not killed (Figure 6). A summary of all the figures 6, 8, and 9 are located in Table 2. The DDAW treatment acts as the control in this experiment. For chromium concentrations in solution, all of the sites except O22 exhibited an increase over time. The results from O22 show a decrease followed by an increase.

With the influence of wetting and drying established, the possible role of aerobic microbes was investigated. The first microbial sterilizer investigated was formaldehyde. The results of the formaldehyde treatment can be seen in Table 2 and Figure 8. The general results for the formaldehyde treatment were not consistent amongst all the sites. Four different types of trends were seen. The graphs for site J19 and site O22 showed a decrease over time of chromium concentration in solution. The graphs for N23, P25, and K22 had one peak. Finally, the graph for J23 showed a decrease followed by an increase of chromium in solution. The DDAW treatment and the formaldehyde treatment do not exhibit similar trends. Possible microbial influences could be inferred by the decreases found in site J19. The percent decrease in chromium concentration in solution was 34% for the site J19 in the formaldehyde treatment. However, the remaining five sites do not illustrate that same general trend. The percent change of chromium concentration in solution in the other five sites is much lower in the formaldehyde treatment than in the DDAW treatment. The percent increase of chromium in solution ranges from 8% to 330%, and the percent decrease 34% to 46% in the formaldehyde treatment. The percent increase of chromium in solution in the DDAW treatment ranges from 96%

to 1373%. Therefore, the influence of microbes on chromium mobility is not supported by the data.

Results from the glutaraldehyde treatment are presented in Table 2 and Figure 9. Two general trends can be seen in the glutaraldehyde results. The first trend is a step increase in chromium released to solution, which can be found in sites J19, N23, P25, and K22. The other general trend is a decrease in chromium released to solution, which can be found in sites J23 and O22. The similarities between the DDAW treatment and the glutaraldehyde treatment can be seen for four sites. However, two sites (J23 and O22) exhibit a decrease in chromium released to solution in the glutaraldehyde treatment. With the differences seen within the glutaraldehyde samples, the influence of microbes is not supported by the data.

The previous work evaluating the influence of microbes on mobility includes the work done by Tagami and Uchida (1996 and 1999). This work does not support nor deny their conclusions that microbes play a role in organically bound metal mobility. The use of formaldehyde and glutaraldehyde as compared to chloroform used by Tagami and Uchida (1996 and 1999) as the microbial inhibitor may account for the changes seen in this project's data. Following the research presented in Alef and Nannipieri (1995) and Jenkinson and Powlson (1976), the fumigants used in the Tagami and Uchida experiments would have destroyed the fine structure of the soil. This study used chemical sterilizers that were suggested for their ability to inhibit a broad spectrum of microorganisms but not destroy the fine soil structure. However, the definite connections seen in the Tagami and Uchida experiments (1996 and 1999) could not be supported by this data. In addition, the data may not be consistent with Tagami and Uchida (1996 and 1999) because of possible complexes that formaldehyde or glutaraldehyde could have formed with iron or manganese in the experiment.

4.0 How does chromium behavior compare to other elements?

The comparisons of chromium to other metal mobility in the presence of wetting and drying are presented in Tables 3 through 10 and Figures 11 through 25. Iron, manganese, and strontium were evaluated for the effects of wetting and drying. Iron and manganese are redox sensitive elements. On the other hand, strontium is controlled by solubility not oxidation reduction reactions. The comparison of the aforementioned elements to chromium for the DDAW treatment is presented in Table 3. The concentration of iron in the DDAW treatment decreases over time for the sites that were always wet and were found at locations where the water table was near the surface (0-0.5 feet) in the field (J23 and K22) (Figure 11). A percent change of 98% for site J23 and a percent change 96% for site K22 mark the sharp decrease of iron concentration. The sites that were either always wet or underwent wetting and drying in the field show a general decreasing trend of iron released to solution (Figure 11). The cyclicly wet and dry field sites (N23 and P25) and the always dry field site (J19) have percent decreases of iron concentration of 30%, 61%, and 55% respectively. Furthermore, the concentrations of iron in the formaldehyde treatment (Figure 13 and Table 8) and the concentration of iron in the glutaraldehyde treatment (Figure 14 and Table 9) decrease over time.

Table 3: Aqueous results for distilled deionized autoclaved water (DDAW) treatment for the four elements investigated chromium, iron, manganese, and strontium

	J19	N23	P25	J23	K22	O22
Cr	Continually increasing	Continually increasing	Continually increasing	Continually increasing	Continually increasing	Decrease followed by increase
Fe	Decrease to steady state	Initial decrease followed by increase	Initial decrease followed by small increase	Sharp Decrease to steady state	Sharp Decrease to steady state	Single peak
Mn	Increasing to steady state	Continually increasing	Single peak	Single peak	Continually increasing	One, broad peak
Sr	Single, broad peak	Single peak	Single peak	Single peak	Single peak	Continually Decreasing

Table 4: Aqueous results for the formaldehdye treatment for the four elements investigated chromium, iron, manganese, and strontium

	J19	N23	P25	J23	K22	O22
Cr	Continually decreasing	One peak	One, broad peak	Decrease followed by increase	One, broad peak	Decrease
Fe	Sharp Decrease to steady state	Decrease to steady state	Sharp Decrease to steady state	One peak	Sharp Decrease to steady state	Sharp Decrease to steady state
Mn	Continually decreasing after initial increase	One, broad peak	One, broad peak	Increase followed by decrease	Two broad peaks	Sharp Decrease to steady state
Sr	Continually decreasing	Two peaks	Single peak	Continually increasing with sharp decrease at end	Two peaks	Single broad peak

Table 5: Aqueous results for the glutaraldehyde treatment for the four elements investigated chromium, iron, manganese, and strontium

	J19	N23	P25	J23	K22	O22
Cr	Step increasing	Step increasing	Step increasing	Decrease to steady state	Step increase	Decrease to steady state
Fe	Sharp Decrease to steady state	Decrease to steady state	Decrease to steady state	Sharp Decrease to steady state	Sharp Decrease to steady state	Sharp Decrease to steady state
Mn	Steady state	Single peak	Single peak	Single peak	Single peak	Sharp Decrease to steady state
Sr	Continually decreasing	Single peak	Single peak	Single peak	Single peak	Single, broad peak

Table 6: Aqueous results for the always wet treatment for the four elements investigated chromium, iron, manganese, and strontium

	J19	N23	P25	J23	K22	O22
Cr	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing
Fe	Step decreasing	Continually decreasing	Continually decreasing	Step decreasing	Continually decreasing	Continually decreasing
Mn	Step decreasing	Continually decreasing	Continually decreasing	Step decreasing	Continually decreasing	Continually decreasing
Sr	Flat	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing	Flat

Table 7: Aqueous results for the bimonthly treatment for the four elements investigated chromium, iron, manganese, and strontium

	J19	N23	P25	J23	K22	022
Cr	Sharp peak with return to initial conditions	Two peaks	One, broad peak	Broad peak decrease to steady state	Sharp peak with return to initial conditions	Decrease to steady state
Fe	Three peaks	Step decreasing	Step decreasing	Two peaks	One peak	One peak
Mn	Bumpy decrease	Two peaks	One, broad peak	Two peaks	One peak	Bumpy decrease
Sr	One peak with step decrease	One, broad peak	One peak	Three peaks	Three peaks	Two, broad peaks

Table 8: Aqueous results for iron for the four treatments DDAW, Formaldehyde (F), Glutaraldehyde (G), Always Wet (AW), and Bimonthly (BM) for the Sample Locations

	J19	N23	P25	J23	K22	022
DDAW	Decrease to steady state	Initial decrease followed by increase	Initial decrease followed by small increase	Sharp Decrease to steady state	Sharp Decrease to steady state	Single peak
F	Sharp Decrease to steady state	Decrease to steady state	Sharp Decrease to steady state	One peak	Sharp Decrease to steady state	Sharp Decrease to steady state
G	Sharp Decrease to steady state	Decrease to steady state	Decrease to steady state	Sharp Decrease to steady state	Sharp Decrease to steady state	Sharp Decrease to steady state
AW	Step decreasing	Continually decreasing	Continually decreasing	Step decreasing	Continually decreasing	Continually decreasing
BM	Three peaks	Step decreasing	Step decreasing	Two peaks	One peak	One peak

Table 9: Aqueous results for manganese for the four treatments DDAW, Formaldehyde (F), Glutaraldehyde (G), Always Wet (AW), and Bimonthly (BM) for the Sample Locations

	J19	N23	P25	J23	K22	O22
DDAW	Increasing to steady state	Continually increasing	Single peak	Single peak	Continually increasing	One, broad peak
F	Continually decreasing after initial increase	One, broad peak	One, broad peak	Increase followed by decrease	Two broad peaks	Sharp Decrease to steady state
G	Steady state	Single peak	Single peak	Single peak	Single peak	Sharp Decrease to steady state
AW	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing
BM	Bumpy decrease	Two peaks	One, broad peak	Two peaks	One peak	Bumpy decrease

Table 10: Aqueous results for strontium for the four treatments DDAW, Formaldehyde (F), Glutaraldehyde (G), Always Wet (AW), and Bimonthly (BM) for the Sample Locations

	J19	N23	P25	J23	K22	O22
DDAW	Single, broad peak	Single peak	Single peak	Single peak	Single peak	Continually Decreasing
F	Continually decreasing	Two peaks	Single peak	Continually increasing with sharp decrease at end	Two peaks	Single broad peak
G	Continually decreasing	Single peak	Single peak	Single peak	Single peak	Single, broad peak
AW	Flat	Continually decreasing	Continually decreasing	Continually decreasing	Continually decreasing	Flat
BM	One peak with step decrease	One, broad peak	One peak	Three peaks	Three peaks	Two, broad peaks

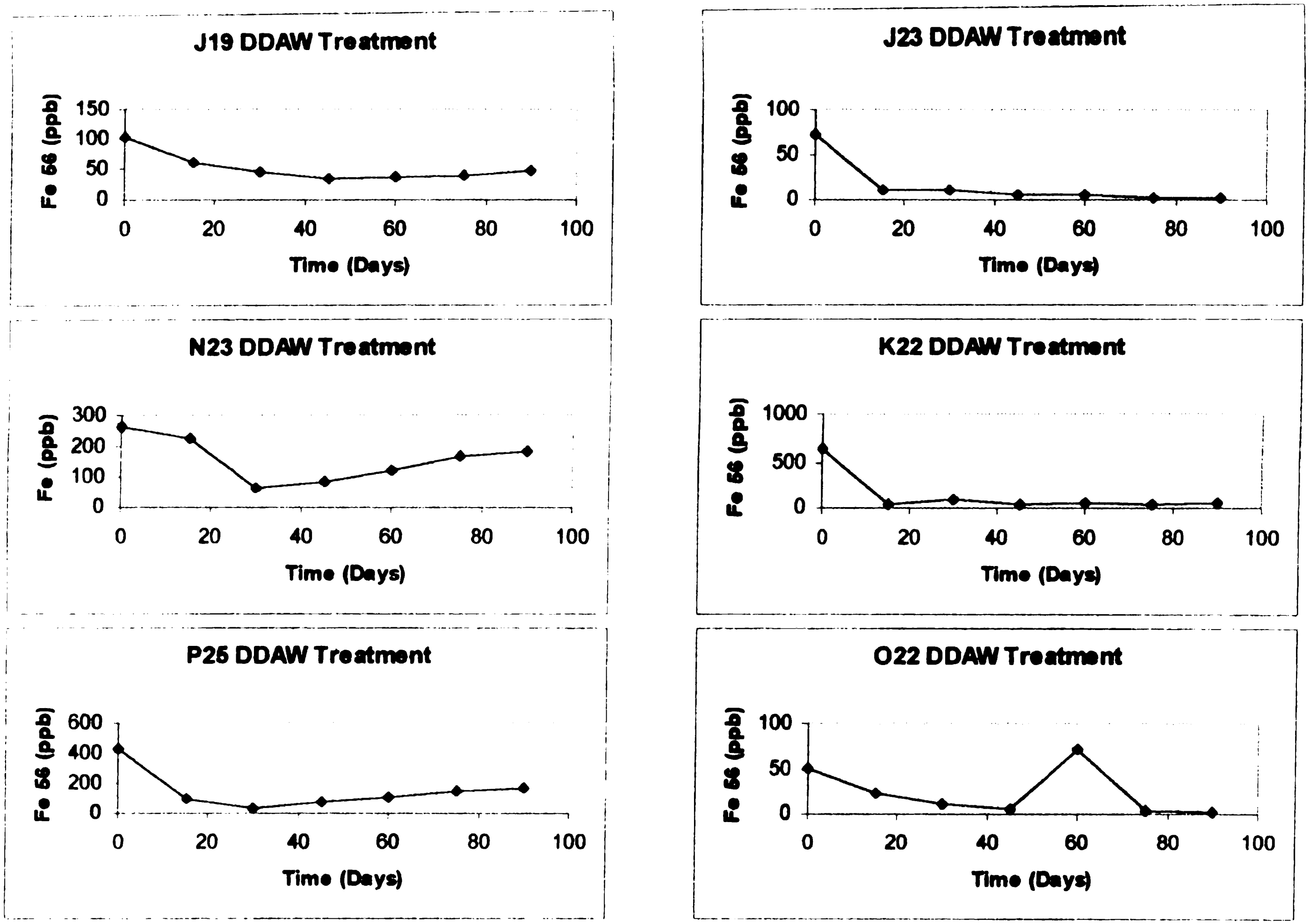
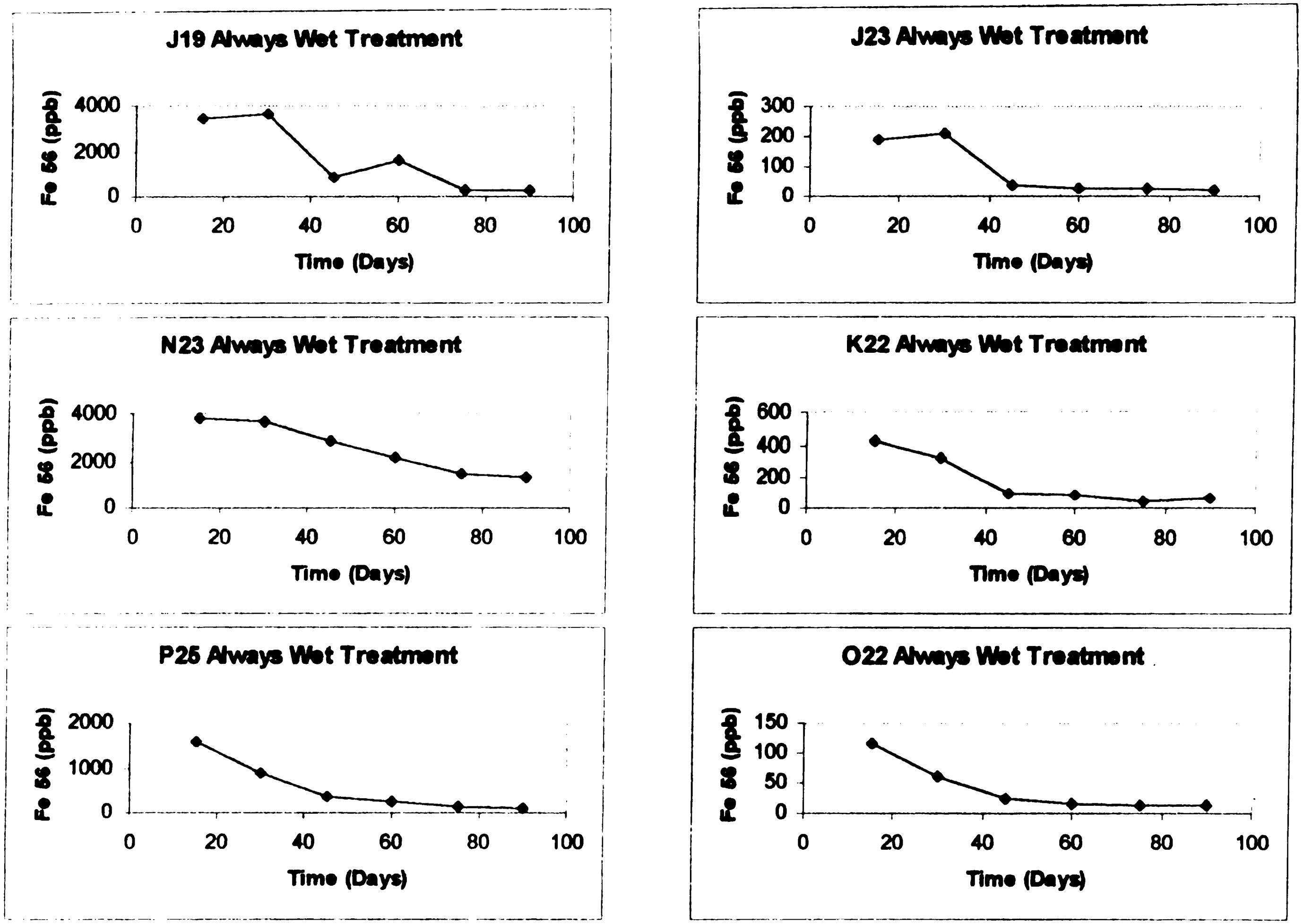


Figure 11: Iron vs. time for DDAW Treatment


J19 Always Wet Treatment

J23 Always Wet Treatment

N23 Always Wet Treatment

K22 Always Wet Treatment

P25 Always Wet Treatment

O22 Always Wet Treatment

Figure 12: Iron vs. time for always wet treatment

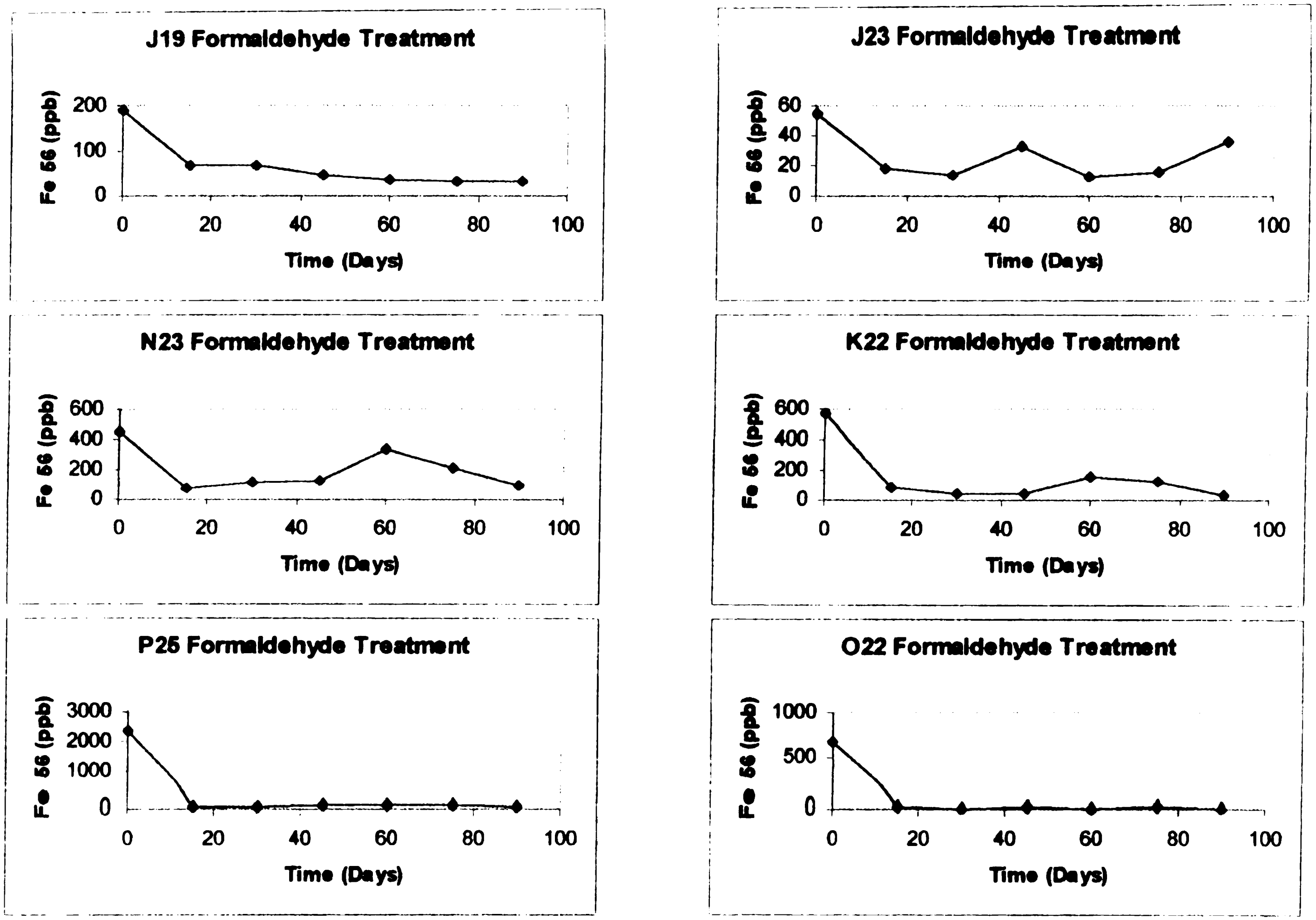


Figure 13: Iron vs. time for formaldehyde treatment

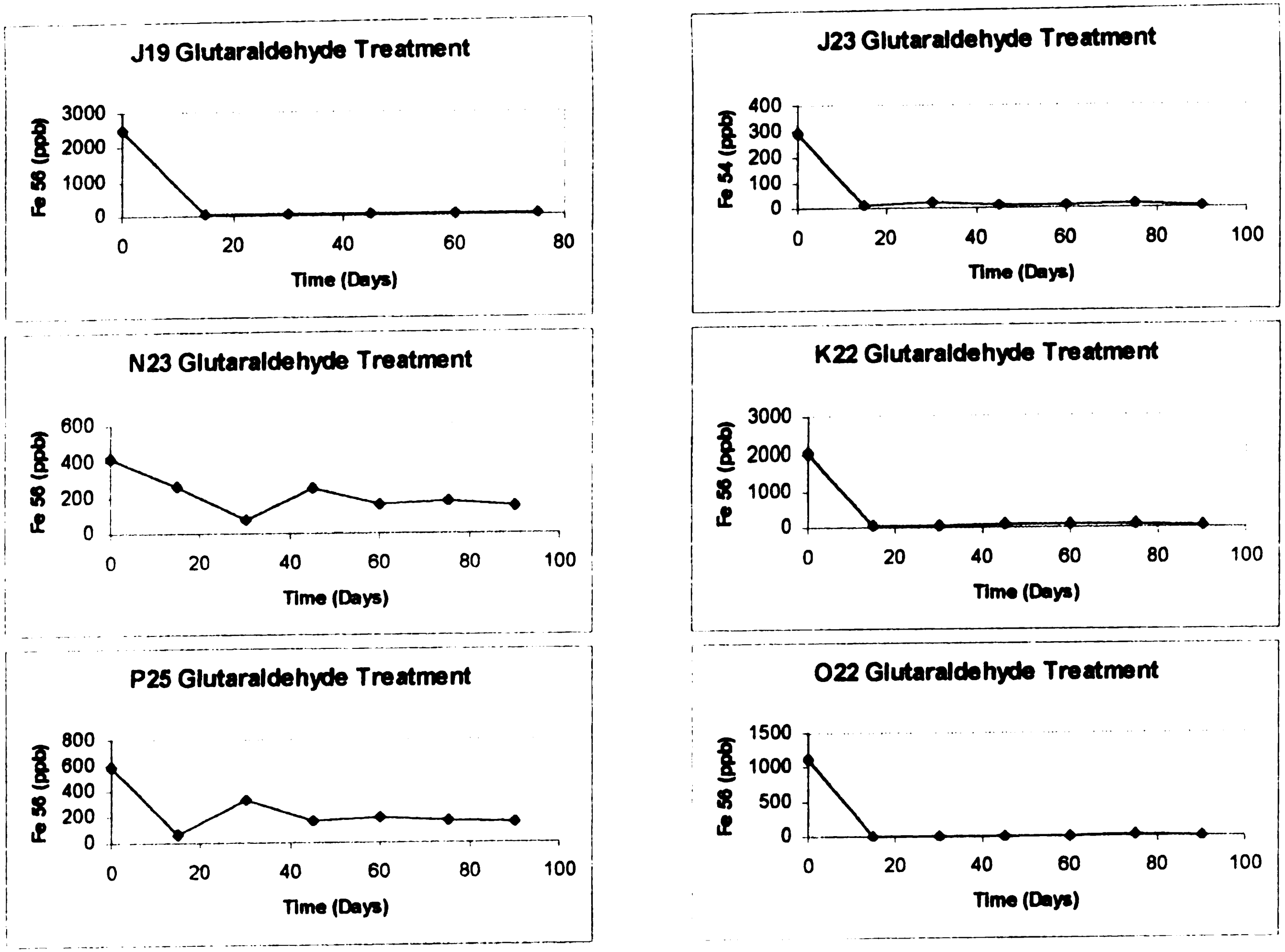


Figure 14: Iron vs. time for glutaraldehyde treatment

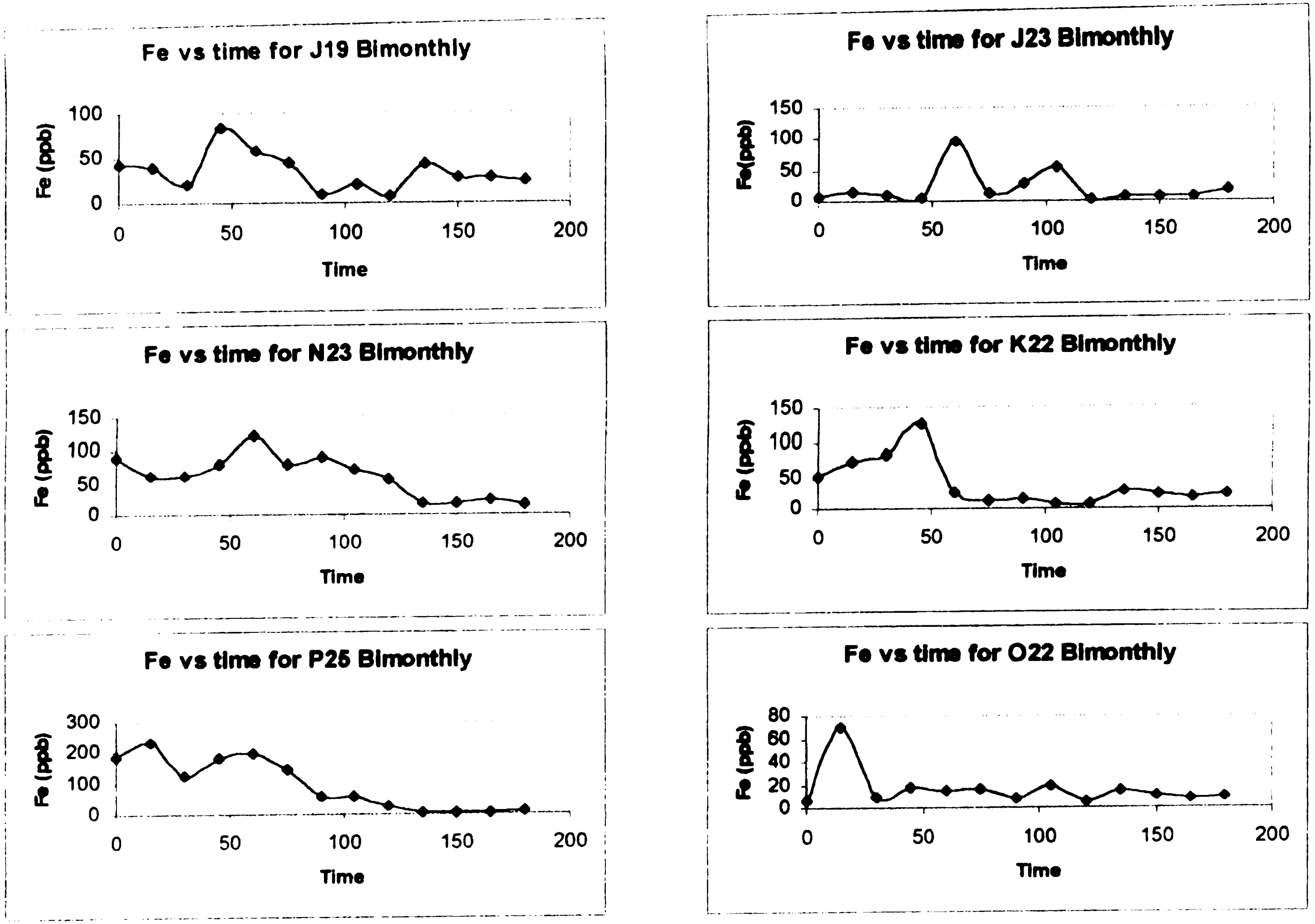


Figure 15: Iron vs. time for bimonthly treatment

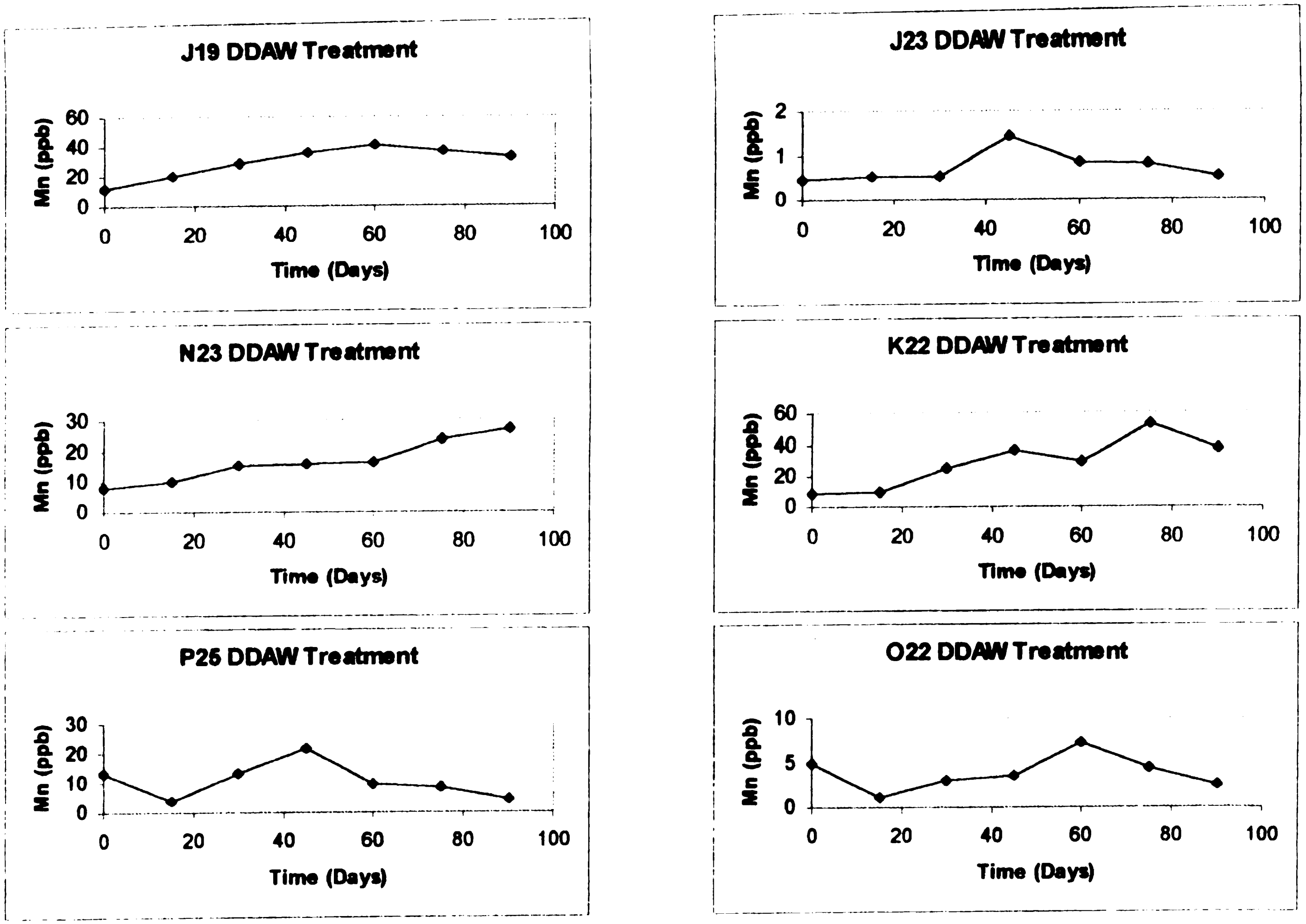


Figure 16: Manganese vs. time for DDAW treatment

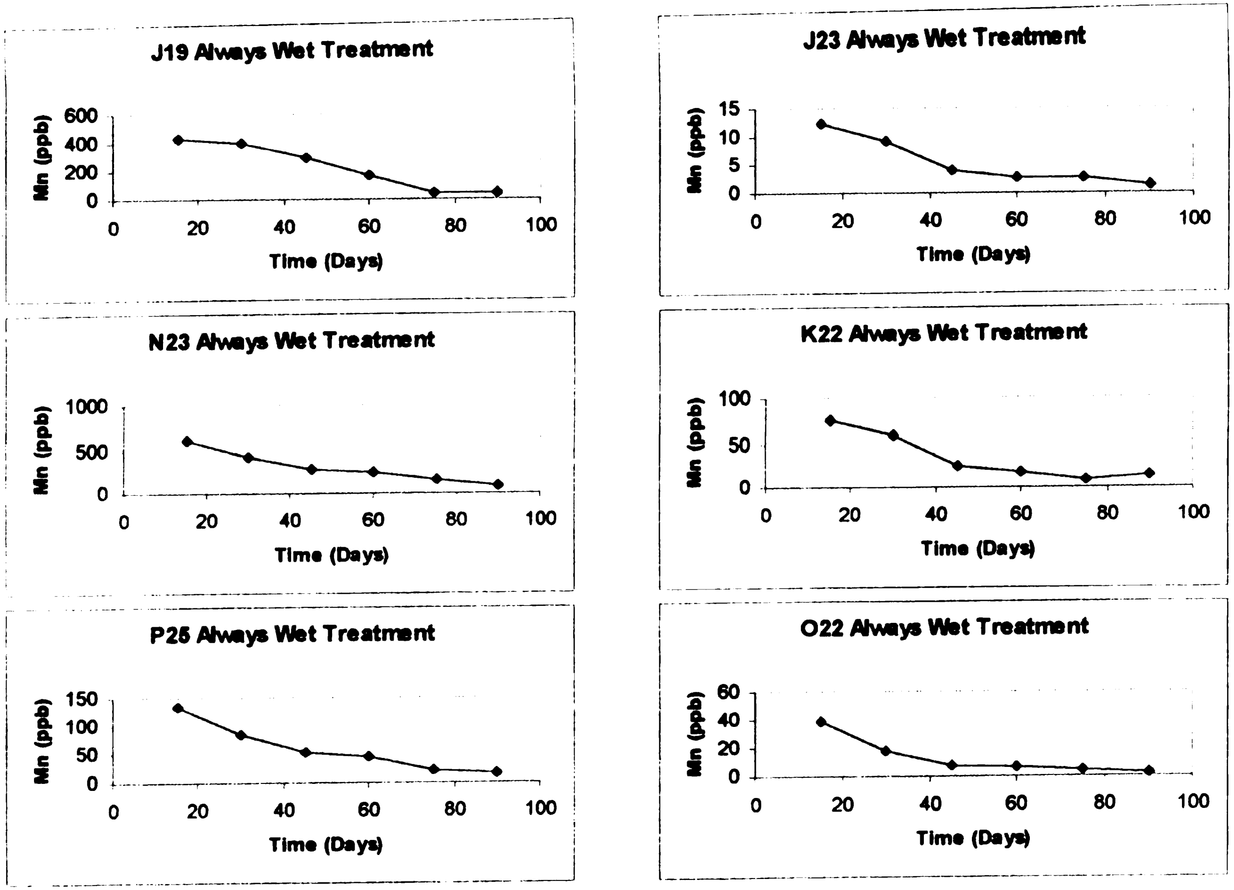


Figure 17: Manganese vs. time for the always wet treatment

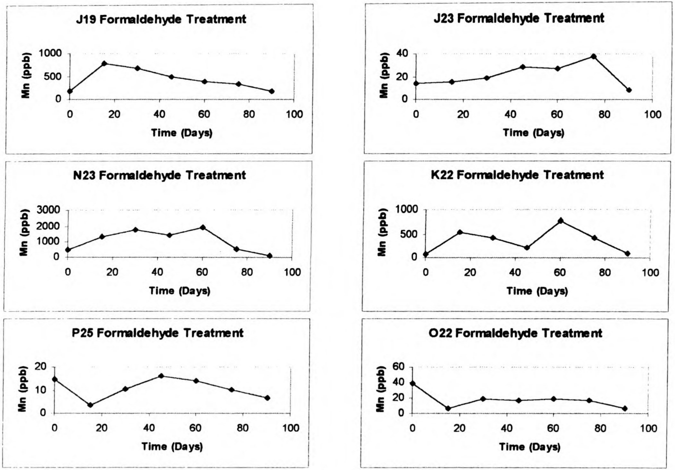


Figure 18: Manganese vs. time for the formaldehyde treatment

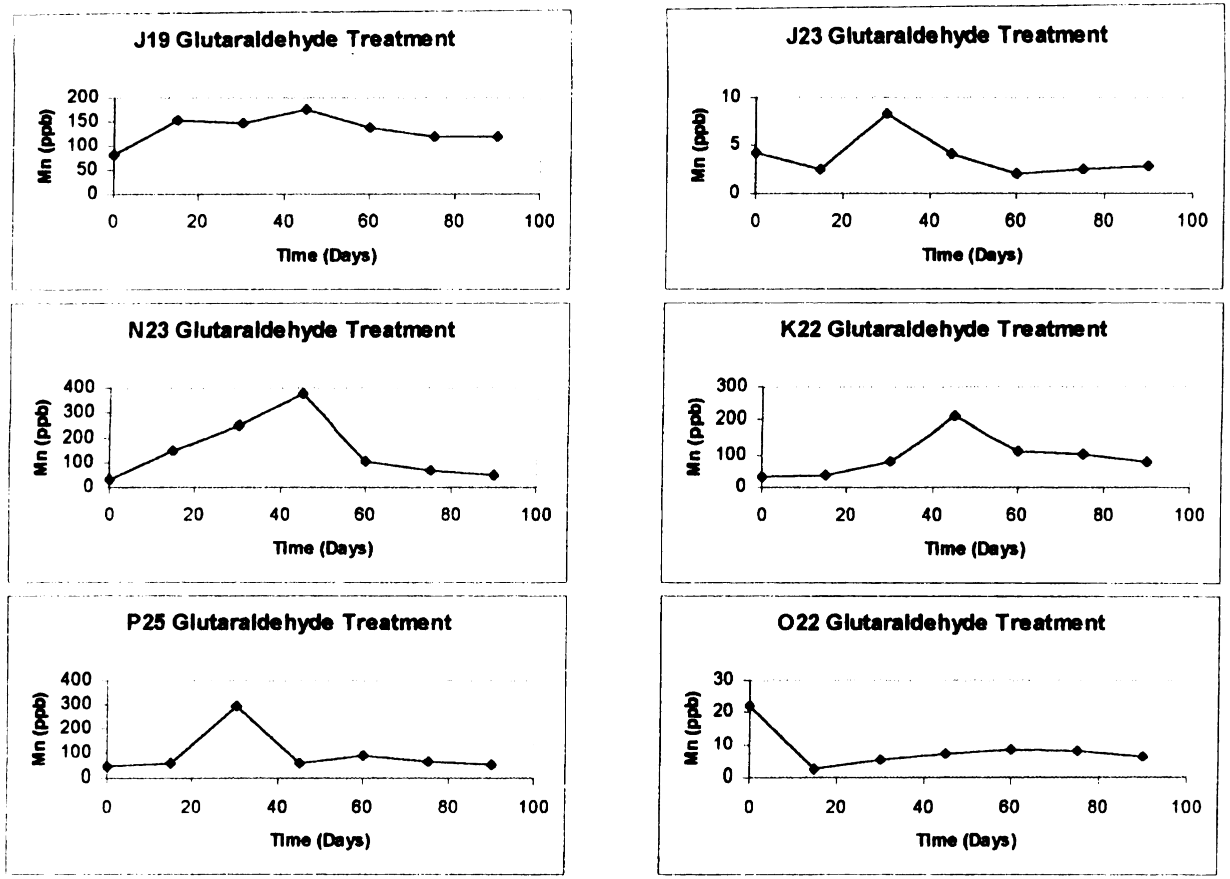


Figure 19: Manganese vs. time for the glutaraldehyde treatment

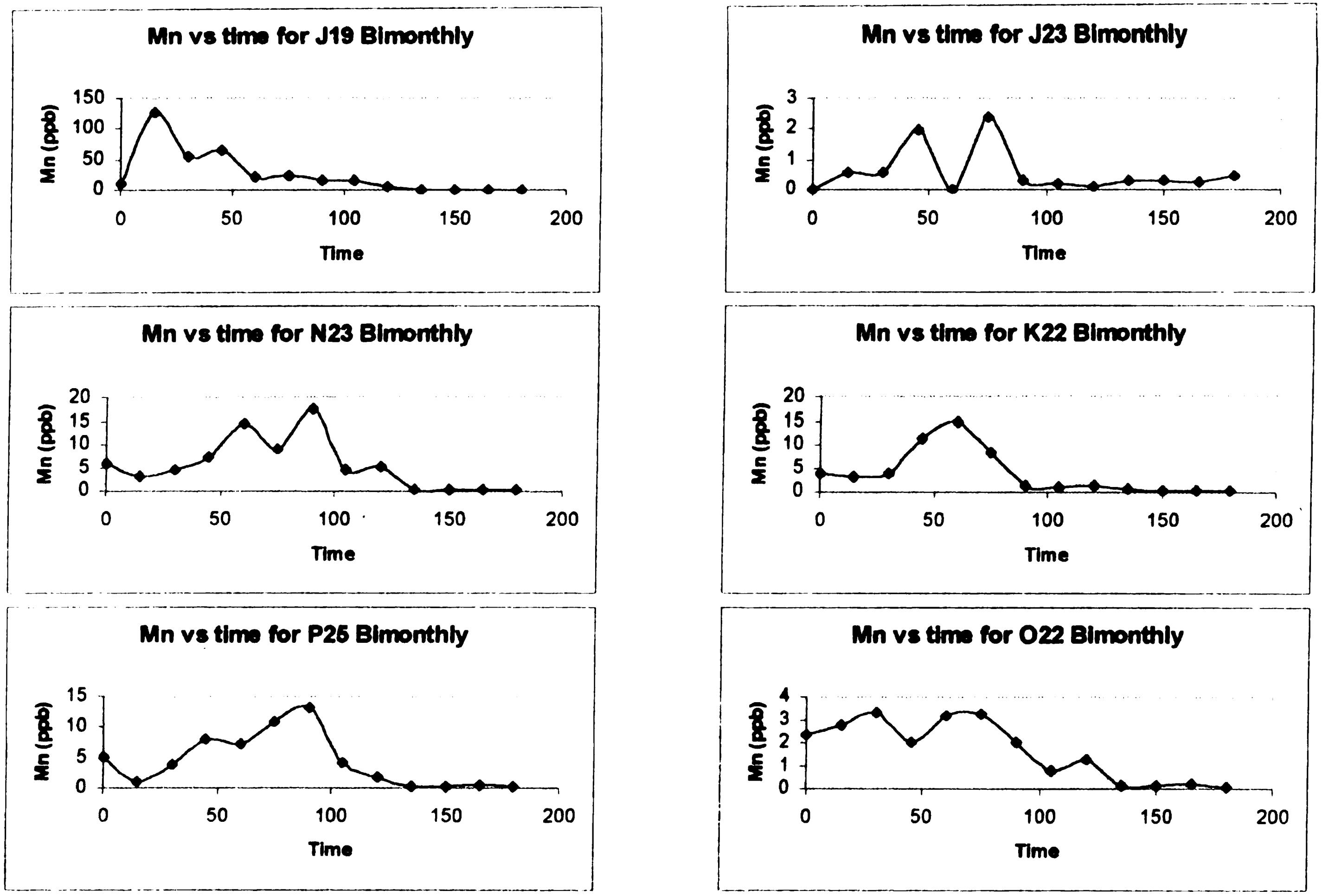


Figure 20: Manganese vs. time for bimonthly treatment

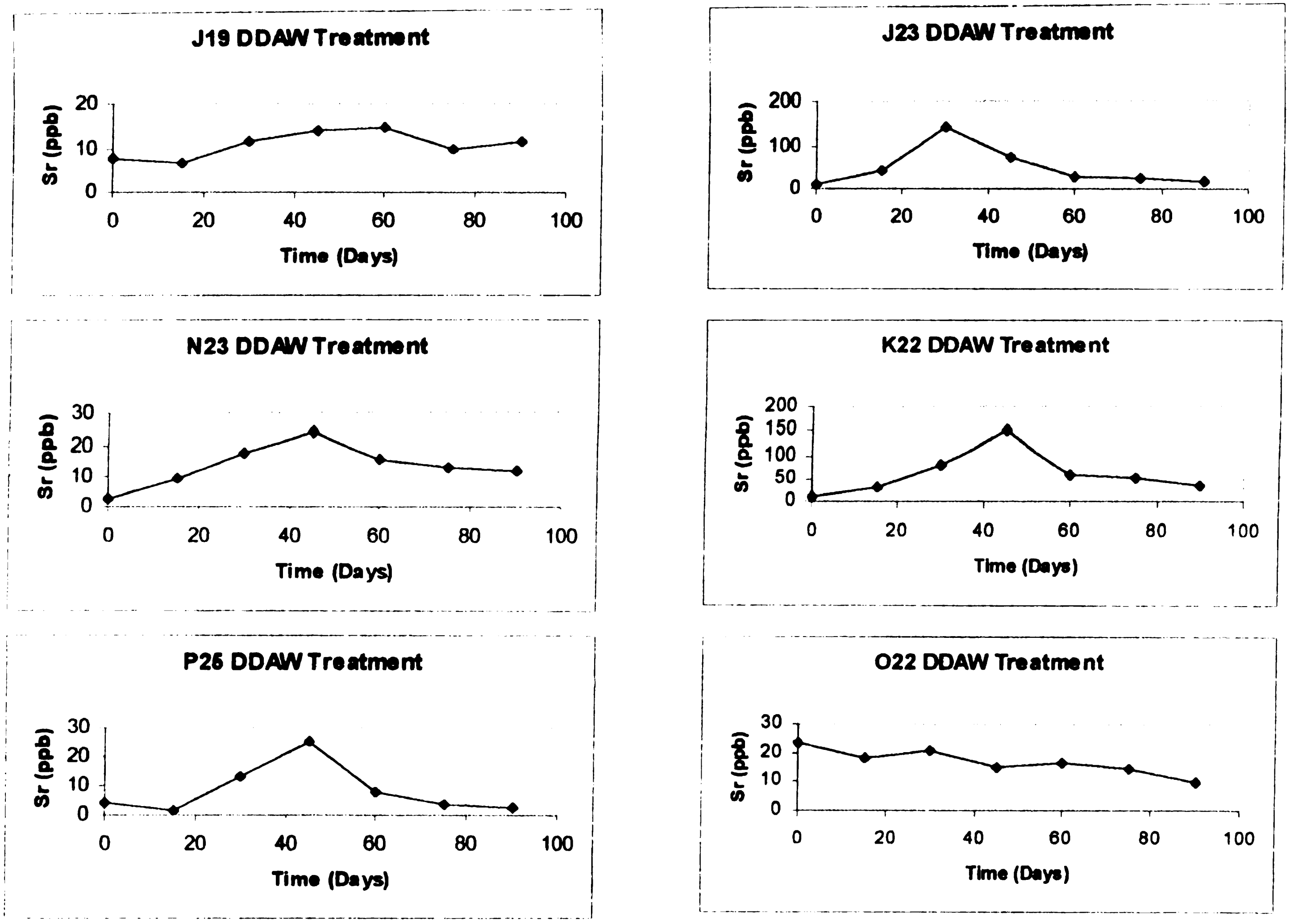


Figure 21: Strontium vs. time for DDAW treatment

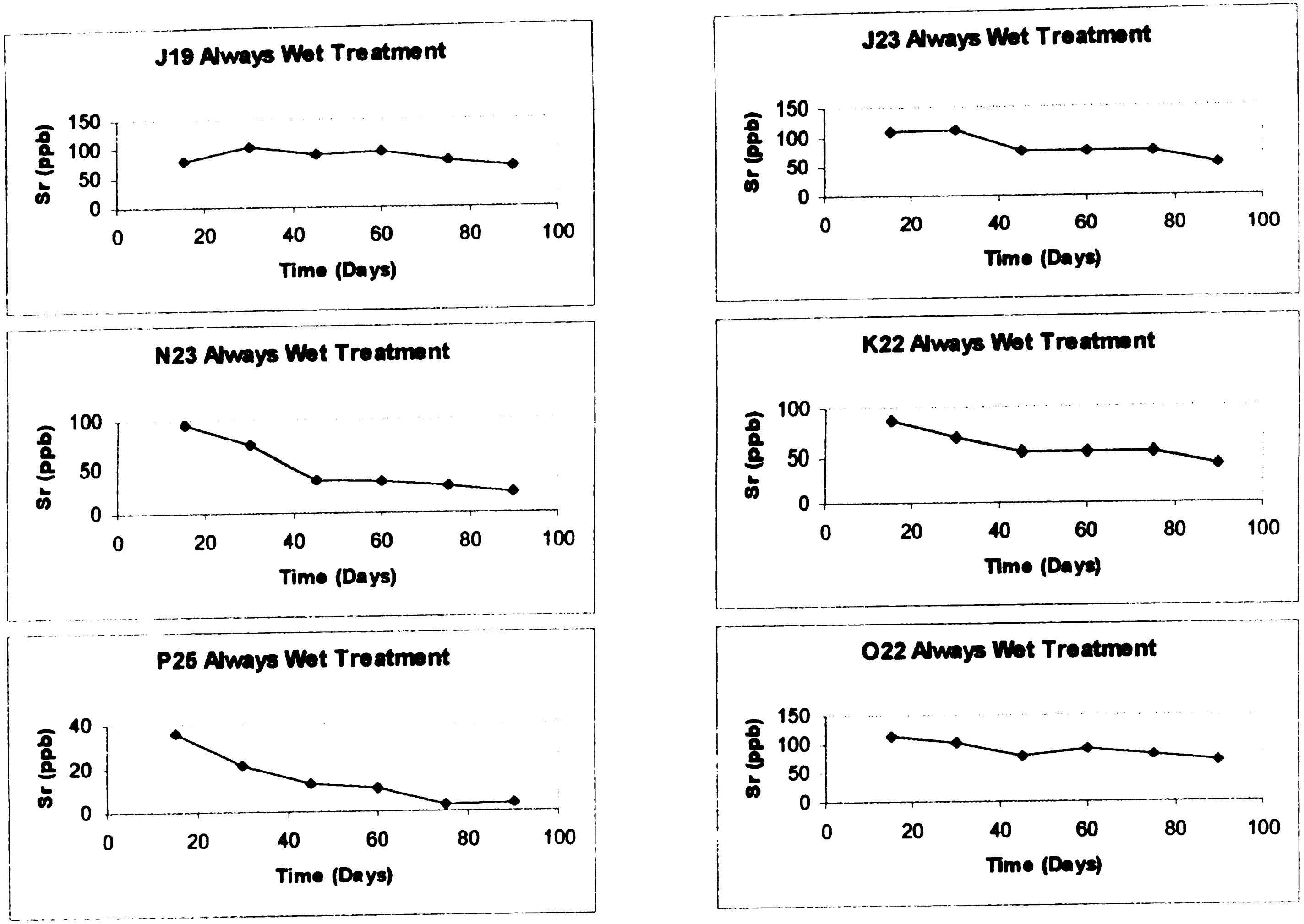


Figure 22: Strontium vs. time for the always wet treatment

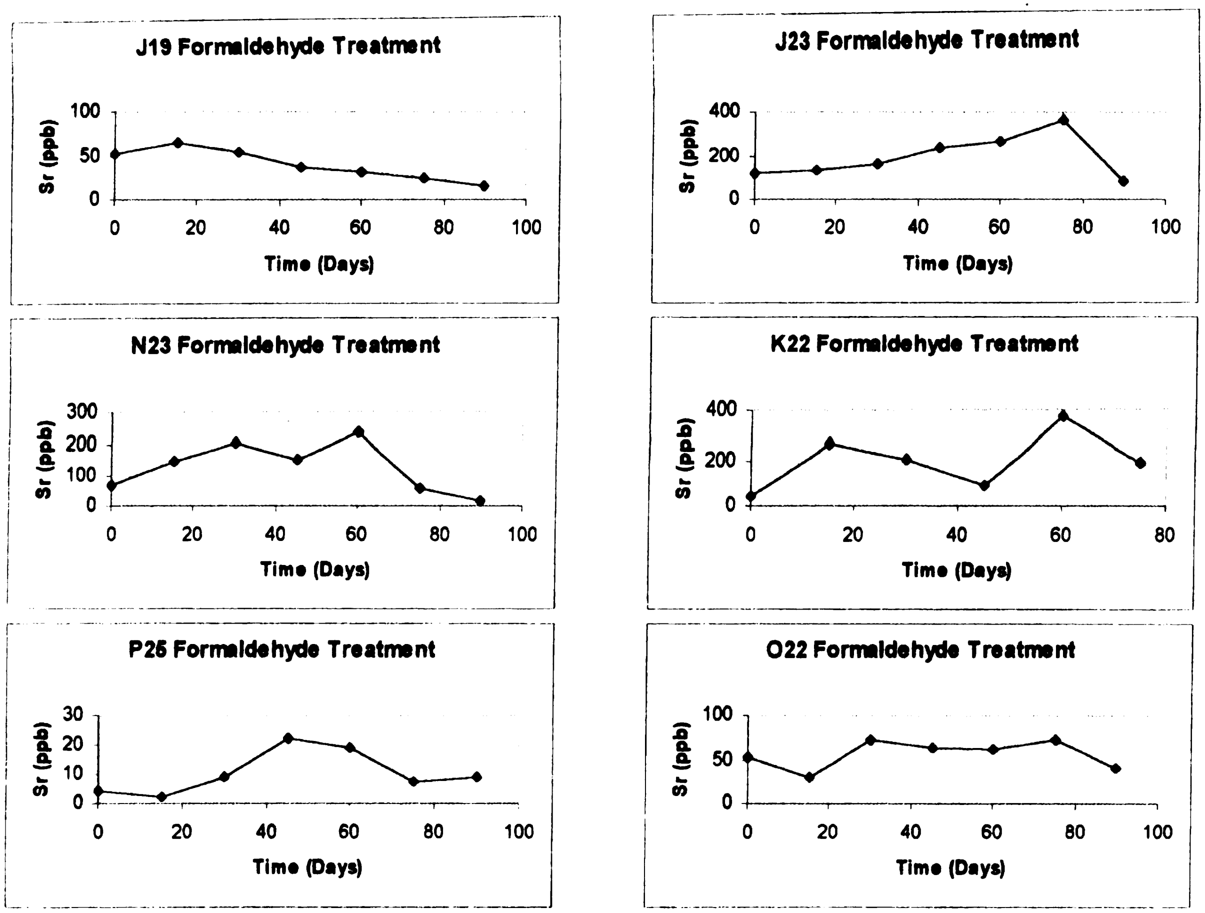


Figure 23: Strontium vs. time for the formaldehyde treatment

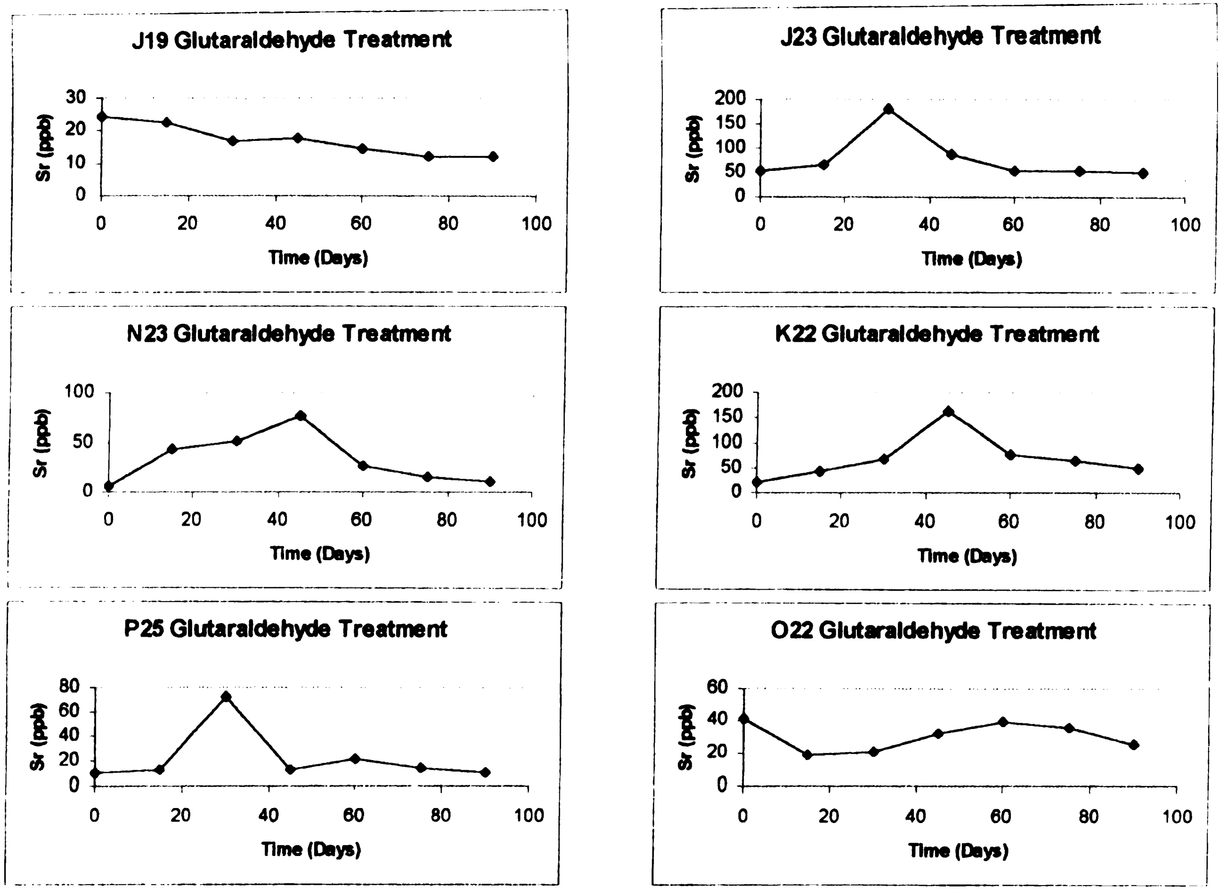


Figure 24: Strontium vs. time for the glutaraldehyde treatment

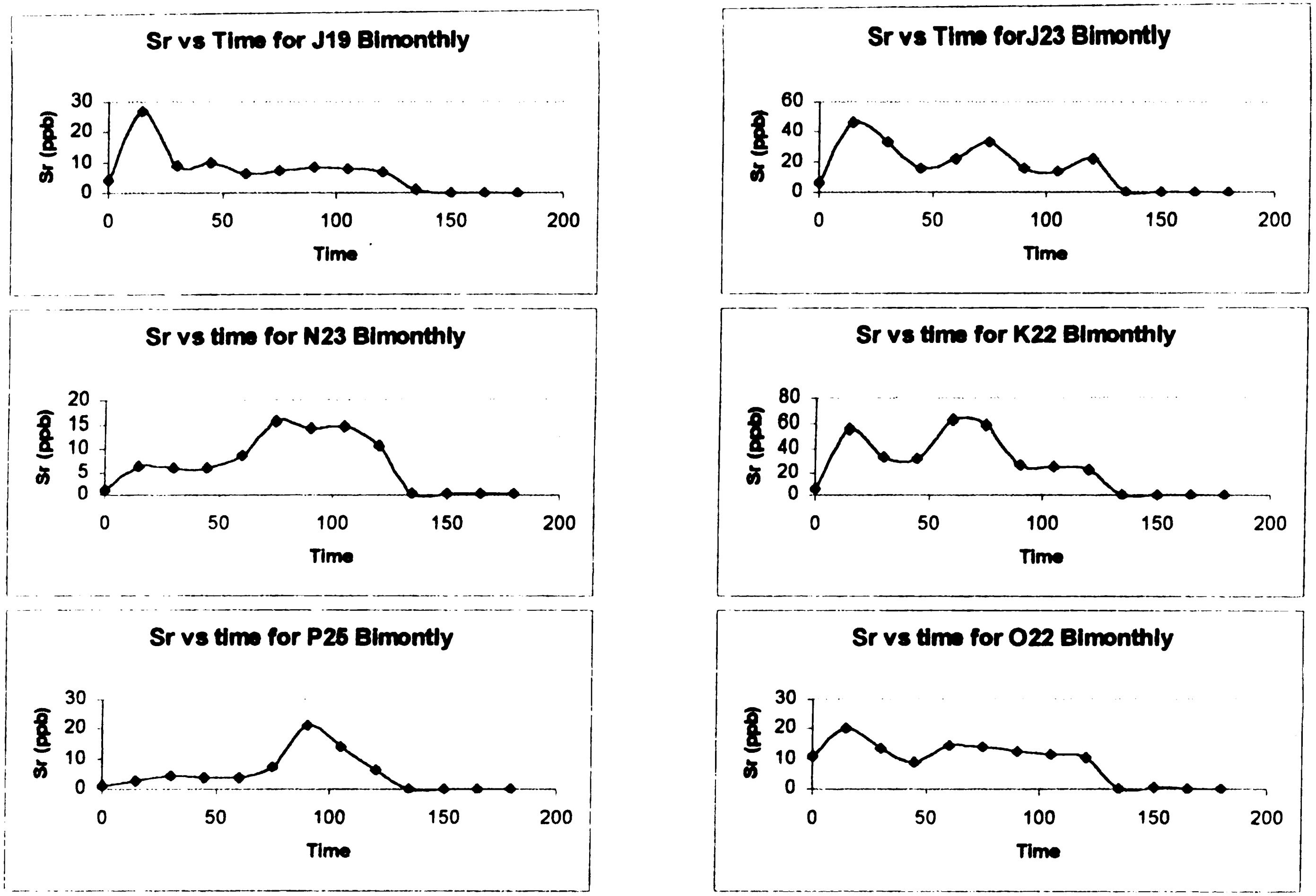


Figure 25: Strontium vs. time for bimonthly treatment

Manganese concentrations in the DDAW treatment increase over time in samples N23 and K22 (Figure 16). The percent increase of manganese concentration for sites N23 and K22 were 285% and 362% respectively. J19, J23, P25, and O22 have a portion of their graphs of manganese concentration vs. time that increases during the experiment. Manganese concentrations for the formaldehyde and glutaraldhyde treatments initially increase in sites J19 and N23 (Figures 18 and 19). In the formaldehyde treatment, P25 manganese concentration in solution increases after a decrease between time zero and time equal to 15 days. After the increase the concentration of manganese decreases in P25 for the remainder of the experiment.

Strontium concentrations decrease over time after an increase that peaks between day 30 and 60 depending on the sample for the DDAW treatment (Figure 21). The formaldehyde treatment (Figure 22) and the glutaraldehyde treatment (Figure 23) had a more variable trend over time.

Iron cycling is a possible mechanism that controls chromium mobility in wetting and drying. Iron cycles between the +2 and +3 states. The reduced state of iron, Fe (II), oxidizes to Fe (III). This oxidation and subsequent precipitation of ferric hydroxide occurs rapidly in the presence of oxygen (McBride, 1994). Dissolved Fe (II) undergoes oxidation in the drying phase of the experiment where the completely saturated soil becomes completely dry. The oxic phase of iron is Fe (III) which forms an insoluble precipitate of Fe (hydro)oxides (e.g. $Fe(OH)_3$) (Stumm and Morgan, 1996). Chromium is adsorbed by Fe (hydro)oxides (Stumm and Morgan, 1996). Therefore, the cycling of iron could impact the liberation of chromium to solution. The increase in iron concentration in the rewetting water could indicate that the sensitive redox boundary described in McBride (1994) was reached, and the Fe (III) (hydro)oxide that adsorbs Cr (III) released the chromium to solution. Furthermore, chromium may also be adsorbed by Mn (hydro)oxides (Stumm and Morgan, 1996). Mn (III/IV) reduces to Mn (II) at a higher redox potential than Fe (III) to Fe (II) (Stumm and Morgan, 1996). Therefore, the cycling of manganese could also affect the amount of chromium in solution. From the manganese data in Figure 17, some increased concentrations of manganese in solution, especially in site N23, leads to a conclusion that manganese cycling has an impact on chromium mobility in wetting and drying environments.

5.0 Summary of Results and Discussion

Is there evidence that wetting and drying enhances chromium mobility? Yes, the research points to a definite influence and enhancement of chromium mobility from wetting and drying. Does the duration of drying affect chromium mobility? Yes, the degree of saturation validates the importance of wetting and drying. The more that the soils are dried out the more chromium is eluded to solution when re-wet. Soils that were dried without a filter over the drying vessel showed an increase in chromium over time while on the other hand semi-dried soils that were capped with a filter or always wet soils decreased in chromium concentration in solution over time. Do aerobic microbes play a role in chromium mobility during wetting and drying? There was no conclusive evidence about the role of aerobic microbes in wetting and drying. How does chromium behave compared to other elements? The other elements investigated behaved differently than chromium. Chromium concentrations in solution increased over time while strontium concentrations in solution decreased over time. The redox sensitive elements, iron and manganese, behaved for the most part differently than chromium in solution with the exception of a few samples and/or treatments (e.g. sample N23 in the DDAW treatment for manganese and chromium) that behaved similarly.

CONCLUSION

1.0 Summary

The research examined the role of wetting and drying of soils on chromium and other metal mobility in soils. Past research (Haynes and Swift, 1989 and 1991; Westfall et al., 1973; Crozier et al., 1995; Hall and Hall 1996; Tagami and Uchida, 1996 and 1999; Icopini et al., 1997, 1998, and 1999; and Ellis 1999) provided the framework for this project. Results from the treatments indicate that wetting and drying increases chromium concentrations in solution from soils that are dried and re-wet.

This study used multi-element analysis on the ICP-HEX-MS to study a variety of elements and their response to wetting and drying including chromium, iron, manganese, and strontium. From previous researchers (Icopini et al., 1997, 1998, and 1999; Ellis, 1999; and Haynes and Swift, 1991) and this study, four questions were addressed (1) Is their evidence that wetting and drying enhances chromium mobility? (2) Does the duration of drying affect chromium mobility? (3) Do aerobic microbes play a role in chromium mobility during wetting and drying? (4) How does chromium behave compared to other elements?

Chromium released to solution during organic matter degradation may be an important mechanism enhancing chromium mobility during wetting and drying. This was inferred from the DDAW treatment where chromium concentrations in solution increased and strontium concentrations in solution decreased. Chromium, which is mainly associated with organic matter, was released to solution during wetting and drying cycles, and strontium, which is mainly associated with carbonates, was not released to solution during wetting and drying cycles.

Iron and manganese cycling may be important in chromium mobility. The possible liberation of chromium by iron and/or manganese cycling was studied by observing the concentrations and trends of iron and manganese. Chromium concentrations in solution increased when undergoing wetting and drying and decreased under always wet conditions. The increase of chromium in solution coincides with the description of iron and manganese cycling by McBride (1994), Stumm and Morgan (1996). From the results, iron cycling plays a role in chromium mobility; however, manganese cycling may be more important in chromium adsorption and subsequent release in wetting and drying environments.

The solubilization or detachment of soil particles containing chromium may be a mechanism of enhancing chromium mobility. This mechanism could be inferred from the increase in chromium concentration in solution in the DDAW treatment. These results correspond to the initial observations of the intact soil core microcosm (Icopini et al., 1998) where they concluded that the initial high concentrations of chromium were due to solubilization or detachment of soil particles containing chromium.

2.0 Environmental Significance and Sources of Error

Chromium is naturally found in two valence states Cr (III) and Cr (VI). Chromium (III) is required by humans along with insulin to maintain proper blood sugar levels (Harte et al., 1991). Cr (III) is considered safe and necessary to a daily intake of 0.20 mg/day (Harte et al., 1991). However, Cr (VI) is highly toxic and guidelines regarding Cr (VI) exposure has been set the EPA. The primary drinking water standard is 50 ppb. The water quality standard for the protection freshwater aquatic life is 11 ppb (Harte et al., 1991).

Ellis (1999) and Icopini et al. (1997, 1998, and 1999) evaluated soil partitioning. From their work, the soil partitioning at the site was linked to two major phases. Those phases were the moderately reducible phase, which targets Fe-oxides/hydroxides, and the oxidizable phase that targets organic matter. The mechanisms that control chromium mobility discussed in the results and discussion section are consistent with the environmental assessment of the partitioning of chromium in the environment at the wetland site presented by Ellis (1999) and Icopini et al. (1997, 1998, and 1999).

Variability and error analysis will be discussed in this section. The first issue is re-freezing. The fine structure of the soil may have been affected by the freezing procedure. Since the concentrations of metals in solution are very small in comparison to the concentration of the soil the fine structure and small-scale variations in the soil become important.

Dying times and sediment heterogeneity are variable in this experiment. Variations in the soil itself would cause replication to be difficult. Sediments were homogenized on site to ensure a relative sample of sediment from each site for the laboratory experiments. Drying times could have caused more variability. The degree of drying/degree of wetness would greatly affect results as was seen in the duration of drying experiments where the sediments were capped with filters and the

DDAW treatment where the sediments were open to the filtered air of the drying cabinet.

Analytical error and sensitivity was a function of the parameters and limitations of the ICP-HEX-MS. Standards were prepared according to the method presented in appendix IV. All samples were run on the ICP-HEX-MS, and the concentrations of the samples were between the highest and lowest standard concentration. The magnitude of change was presented in the results and discussion section. Some of the overall changes were within the possible error of the ICP-HEX-MS, however, the majority of the samples had an overall percent change of over 30%.

Other factors beyond the microbialcidal effects of the chemical sterilizers that influence metal mobility are difficult to assess. For example, studies have shown propylene oxide, an effective microbial inhibitor, increases all metal concentrations released to solution. In this experiment, iron and manganese may have complexed with glutaraldehyde and/or formaldehyde, which could have altered the concentration of chromium in solution. Further studies would need to be done on possible complexing between iron and manganese with glutaraldehyde and formaldehyde.

3.0 Future Research

Phytoremediation and other in situ techniques are possible remediation strategies for the wetland site. Remediation strategies for the wetland site were discussed in Icopini et al. (1997, 1998, and 1999). The dominant remediation strategy discussed was in situ remediation. This strategy requires that transformation or loss of contaminants occurs. One remediation strategy that has documented transformation potential is phytoremediation. Phytoremediation is the use of green plants to remove or contain contaminants in the environment. Some of the dominant wetland species that are used in constructed wetlands when phytoremediation is desired are cattail (Typha latifolia), bulrush (Scripus lacustris) and reed (Phragmites australis). Those wetland plants have high primary productivity (Buddhawong et al., 2002). Wetland plants in association with aerobic microbes have been found to uptake and convert Cr (VI) to Cr (III). Other possible suggestions for remediation for the wetland site are to keep saturated areas saturated and unsaturated areas unsaturated so as not to induce the mobility of chromium through wetting and drying.

4.0 Questions for further research.

- Would rain in a desert environment act as a catalyst to enhance chromium mobility similar to the cyclic wetting and drying process in wetland environments?
- What are the effects of formaldehyde and glutaraldehyde complexing with iron and manganese?
- What is the best microbial inhibitor to use in metal mobility studies? And in what cases should one utilize fumigants, chemical sterilizers, and/or autoclaving?
- Would phytoremediation decrease the amount of chromium in solution when the wetland is subjected to wetting and drying conditions?

- Would a field study with a broader study of more diverse sites with additional parameters like Eh provide a definite conclusion to the major mechanism controlling chromium mobility in wetting and drying cycles?

APPENDICES

APPENDIX I

APPENDIX I

Method for Nitric Acid Microwave Digestion of Soils (Hewitt and Reynolds, 1990)

1. Weigh and label a watch glass.
2. Place at least 5 grams of soil on a watch glass.
3. Weigh the watch glass and soil.
4. Place the watch glass in a 50°C oven for 24 hours.
5. Re-weigh the watch glass and soil.
6. Place the dried sample into ceramic mortar. Grind into a fine powder with a pestle.
7. Carefully weigh out 0.500 grams of ground sample and place into a teflon digestion vessel.
8. Repeat for each sample and wash the mortar and pestle between each grinding to prevent cross-contamination.
9. Do the same for the Standard Reference Material (SRM)
10. To each sample and the SRM add 10 mL of 15N HNO_3. Make sure no sample remains on the side of the vessel.
11. The blank is a vessel with just nitric acid added for digestion.
12. Seat the pressure membranes in the caps of all the samples, the blank, and the SRM.
13. Screw caps on all vessels.
14. Attach the pressure monitor to any sample not the blank or SRM.

15. A CEM MDS 81D microwave with pressure regulation is used for digestions. Place vessels into a rotary tray inside the microwave. Rotate the tray a few times before starting to assure that the pressure hose will not get caught on any of the vessels.
16. Program the microwave to run 15 minutes at 100% power with pressure regulated to 150 psig maximum and then 20 minutes (0% power) cool down period to allow pressure in the vessels to fall below 10 psig.
17. To each sample, blank, and SRM add 90 mL of distilled deionized water (DDW) after digestion and cool down period.
18. Filter samples through a 0.4 μm Nucleopore filter into an acid washed 120 mL bottle. Condition filter with 10 mL of leachate/DDW.

APPENDIX II

APPENDIX II

Method for TOC 5000A: Organic Carbon Analyzer

1.0 Daily Maintenance:

1. Check paper. Lift cover on top of machine to view paper, if low replace.
2. Check acid in IC reagent container (25% phosphoric), if the acid is low replace with additional acid that can be made using the following formula

(Concentrated dilute acid (25%) x volume being made (250 mL)) / (Concentrated stock phosphoric acid)

3. Check water level in glass humidifier bottle, water level should be between white lines, if not, unscrew black cap on the side of bottle and fill with E-pure water.
4. Make sure drain tubes are not submerged in wastewater.
5. Check amount of water in the rinse/wash bottle, if the water level is low fill with E-pure water.

2.0 Periodic Maintenance:

1. Replace gas cylinder with ultra pure zero air when the gauge reaches 200 psi.
2. Replace CO_2 absorber after 1 year of use.
3. Replace halogen scrubber annually or when discoloration reaches the tip of the tube.
4. Replace microsyringe plunger tip if leakage appears in the syringe barrel.
5. Replace white O-ring on sliding sample injector if running mor than 125 injections per day.

6. Replace dark O-ring every 6 months.
7. Adjust NDIR zero when baseline drift occurs.
8. Check to see if TC catalyst is discolored, and if so replace.
9. Replace TC combustion tube O ring annually.
10. Clean humidifier bottle and replace water yearly, when cleaning add 3 pellets of NaOH.

3.0 Preparation of IC stock solution (1000 ppm)

Dissolve precisely 3.50 grams of Sodium Hydrogen Carbonate and 4.10 grams of Sodium Carbonate Anhydrous, which have both been placed in a 285°C oven for at least 1 hour, into 1 L of E-pure water.

4.0 Preparation of OC stock solution (1000 ppm)

Dissolve precisely 2.125 grams of reagent grade potassium hydrogen phthalate in 1 L of E-pure water.

5.0 Sample Preparation

1. Samples are filtered using an acid washed 0.4 μm filter.
2. Between 5 – 8 mL of the filtrate is placed in an acid washed 8 mL bottle.
3. The samples are then immediately frozen until analysis
4. Thaw samples before analysis.
5. In the small glass containers add 100 μL of Shimadu's Hydrochloric Acid, 2 mL of e-pure water, and 2 mL of sample.

6. After every 15 samples insert a check standard.
7. Place parafilm tightly over all the small glass sample containers.
8. Prepare standards using the IC and OC stock solutions and place in the large glass containers.
9. Place parafilm tightly over all the large glass sample containers.
10. Place all the containers in the auto-sampler tray.

6.0 Beginning a run

(all commands other than function commands must be confirmed by pressing the return key)

1. Carrier gas pressure should be set at 4-5 kg/cm.
2. Carrier gas flow should be at 150 mL/min.
3. Turn power on.
4. Must press F5 to Initialize auto sampler.
5. After initializing is complete select F1 next to access main menu screen.
6. Select #3 General Conditions
7. Turn furnace on by entering 1 (TOC) then press return
8. Furnace takes approximately 1 hour to heat to the proper temperature (680°C)
9. The machine needs to be on 24 hours in advance of running standards or samples
10. From print out options, choose Data & Peak plots or just Data).
11. Press F2 to return to main menu
12. Choose #9 auto sampler
13. Choose type of measurement to be performed (1-5)

14. Enter under IS (initial sample) the location of the first sample vial, then press return. Next enter the location of your final sample (FS).
15. Enter the calibration curve under C1 then press return.

7.0 Calibration/Conditions

1. Select type of curve (1=TC and 2=IC)
2. Enter values for the 1st standard concentration and press return, then enter the standard position that it is in (S1-S8).
3. Repeat for 2nd, 3rd, and 4th standards, depending on how many you have (a re-calibration should be done every 15 samples).
4. Set number of injects and maximum number of injects (recommended 4 out of 7).
5. If doing NPOC with IC check, set sparge time to 2 minutes.
6. Repeat these steps as many times as necessary.
7. All curves will be under the C1 column.
8. Before starting a run check the ready state conditions choose #6 monitor
9. Make sure the baseline is at or near zero.
10. To adjust the baseline, move small square cover at top of machine labeled optical zero to access the adjustment screw. The screw is in the opening with the copper tube, closest to the front of the machine.
11. Make sure the furnace is at the appropriate temperature.
12. Choose F2 to go back to main menu

13. Set needle washes (W) equal to 3 and number (NO) and maximum number (MAX) of sample injections (recommended 3 out of 5).
14. Make sure the arrows on the machine and the carousel line up.
15. Choose F1 NEXT
16. Press the START button.

8.0 Shutdown Procedures

1. To shutdown first go to General Conditions and turn furnace off, than return to the main menu F2.
2. Choose #7 Standby Options and select finish.
3. A proper shutdown will take approximately 30 minutes
4. Turn off the power switch.

APPENDIX III

Table 11. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J19 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
J19A1-1	4.34	0.27	75.2	0.94	0.13	215.29	8.47	74.9	1679.19
J19A1-2	0.28	0.18	35.89	0.23	14.13	86.36	1.2	31.51	413.88
J19A1-3	3.58	0.19	32.88	0.28	1.86	150.51	2.25	15.78	851.17
J19A1-4	2.14	0.21	35.35	0.34	1.39	173.45	3.11	24.11	1004.69
J19A1-5	2.02	0.16	24.65	0.34	0.33	201.66	2.41	51.61	782.24
J19A1-6	1.35	0.08	29.23	0.28	0.58	122.84	1.89	21.22	756.29
J19A1-7	0.45	0.06	18.86	0.33	0.29	109.52	2.19	15.79	742.71
J19A1-8	1.69	0.1	32.13	0.21	0.25	102.88	1.87	37.86	913.25
J19A1-9	1.97	0.01	19.69	0.16	0.23	65.88	1.22	13.7	689.58
J19A1-10	1.88	0.13	31.19	0.14	0.11	49.33	1.49	17.75	701.04
J19A1-11	5.69	0.09	24.83	0.35	0.05	59.83	0.82	9.15	667.32
J19A1-12	4.22	0.14	35.67	0.45	0.11	77.17	3.6	19.34	763.58
J19A1-13	5.93	0.04	18.78	0.45	0.32	45.73	3.76	13.69	567.69
J19A1-14	3.93	0.1	23.56	0.39	0.15	47.9	3.76	95.01	607.85
J19A1-15	4.14	0.02	35.74	0.51	0.21	55.17	4.65	513.41	715.54
J19A1-16	2.53	0	28.49	0.39	0.05	27.97	2.86	12.44	575.28
J19A1-17	1.67	0.09	53.64	0.47	0.03	51.31	1.57	104.66	1057.43
J19A1-18	2.23	0.07	33.09	0.2	0.39	44.24	1.48	29.07	646.49
J19A1-19	2.82	0.03	19.92	0.18	0.14	90.85	1.46	20.66	362.71
J19A1-20	4.25	0.1	22.43	0.23	0.2	100.45	2.92	29.91	571.47
J19A1-21	2.7	0.07	27.44	0.17	0.03	62.03	0.76	8.01	604.25
J19A1-22	2.77	0.09	30.41	0.24	0.38	70.67	0.99	9.79	708.9
J19A1-23	2.73	0.09	26.89	0.19	0.23	70.47	0.96	15.25	706.17
J19A1-24	2.86	0.04	45.67	0.36	0.14	73.92	1.03	10.84	820.4

Table 12. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site J19 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
J19A1-1	24.45	0	4.07	1.32	0.53	13.04	0.95	0	170.51
J19A1-2	21.85	0	3.7	0.56	0.26	7.26	0.18	0.04	23.39
J19A1-3	20.2	0	2.55	0.55	0.18	5.45	0	0	45.67
J19A1-4	23.42	0	3.28	0.54	0.23	6.67	0	0	49.16
J19A1-5	20.87	0	3.79	0.62	0.15	4.97	0.05	0	41.91
J19A1-6	20.92	2.11	2.18	1.06	0.2	5.40	0	0	45.32
J19A1-7	10.54	0	2.1	0.47	0.1	4.07	0	0	42.13
J19A1-8	14.62	0	1.53	0.67	0.27	4.86	0	0	35.41
J19A1-9	3.48	1.2	1.29	0.61	0.14	2.67	0	0	30.38
J19A1-10	1.94	0	0.77	0.47	0.09	3.42	0	0	185.64
J19A1-11	2.58	0	4.99	1.14	0.19	3.99	0.01	0.11	47.77
J19A1-12	8.65	0	2.89	2.48	0.34	5.46	0.44	0.16	157.19
J19A1-13	2.11	6.69	2.77	1.81	0.19	3.13	0.01	0.16	57.96
J19A1-14	3.72	3.3	4.21	1.59	0.2	3.48	0.10	0.12	166.63
J19A1-15	7.27	22.67	4.62	1.58	0.35	5.11	0.27	0.16	84.62
J19A1-16	0.93	0.09	2.49	1.48	0.18	3.78	0.04	0.07	29.65
J19A1-17	4.13	1.03	1.61	2.47	0.54	9.48	0.64	0.13	74.02
J19A1-18	8.3	4.37	1.19	2.80	0.54	5.15	0.30	0.17	37.63
J19A1-19	32.13	2.96	2.36	2.15	0.51	2.36	0.65	0.08	31.6
J19A1-20	40.84	3.99	2.17	2.40	0.69	7.29	0.52	0.14	35.35
J19A1-21	4.8	1.34	1.12	2.08	0.49	4.11	0.18	0.11	35.08
J19A1-22	7.4	0.72	1.24	2.13	0.51	5.09	0.35	0.09	41.94
J19A1-23	9.02	32.87	1.25	3.11	0.58	4.77	0.32	0.16	44.58
J19A1-24	1.92	1.51	1.55	2.14	0.63	6.74	0.47	0.11	95.24

Table 13. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J23 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
J23A1-1	4.34	1.31	13.88	0.25	0.02	44.19	3.03	31.58	2170.92
J23A1-2	0.28	0.28	2.07	0.15	1.5	5.75	0.23	14.23	354.57
J23A1-3	3.58	0.44	17.03	0.85	3.59	18.36	1.52	11.54	3159.2
J23A1-4	2.14	0.36	19.43	0.66	0.58	43.3	2.07	9.72	2631.88
J23A1-5	2.02	0.26	13.08	0.67	0.55	40.39	1.17	18.92	1742.32
J23A1-6	1.35	0.13	9.3	0.58	0.26	34.17	1.66	10.06	1224.34
J23A1-7	0.45	0	1.54	0.65	0.31	5.65	0.69	14.37	464.6
J23A1-8	1.69	0.1	11.74	0.87	0.22	43.37	1.6	21.25	1850.43
J23A1-9	1.97	0.08	6.92	0.67	0.56	42.55	1.3	18.34	1132.28
J23A1-10	1.88	0.19	9.4	0.72	0.02	39.22	2.4	24.15	1305.04
J23A1-11	5.69	0.17	8.19	0.78	0.08	44.43	1.64	303.67	1008.35
J23A1-12	4.22	0.13	9.77	0.99	0.28	36.5	4.24	22.27	1016.08
J23A1-13	5.93	0.11	6.38	1.24	0.18	39.49	4.82	12.17	902.54
J23A1-14	3.93	0.05	7.7	1.02	0.13	26.47	3.94	93.64	778.37
J23A1-15	4.14	0.03	4.94	1.04	0.19	26.05	3.85	195.3	733.06
J23A1-16	2.53	0.03	2.29	0.69	0.2	12.21	2.47	7.91	316.23
J23A1-17	1.67	0.39	9.69	1.02	0.14	26.46	1.57	15.18	896.24
J23A1-18	2.23	0.14	8.82	0.91	0.43	48.66	2.5	41.3	872.87
J23A1-19	2.82	0.17	7.72	1.44	0.07	45.71	3.97	56.08	927.24
J23A1-20	4.25	0.19	5.18	1.96	0.14	66.34	7.63	28.06	878.24
J23A1-21	2.7	0.04	5.37	1.15	0.07	38.45	1.68	6	637.78
J23A1-22	2.77	0.1	5.77	1.37	0.42	44.96	2.12	8.11	716.65
J23A1-23	2.73	0.19	6.9	1.19	0.18	52.7	2.33	5.64	672.51
J23A1-24	2.86	0.05	6.44	1.3	0.14	50.1	1.99	15.34	607.21

Table 14. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site J23 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
J23A1-1	2.89	7.93	4.34	0.99	0.33	32.30	0.62	4.33	16.80
J23A1-2	0	0	0.28	0.56	0.23	6.19	0	2.49	7.19
J23A1-3	0.23	0	3.58	1.01	0.39	46.72	0	1.73	31.63
J23A1-4	0.51	0	2.14	1.22	0.44	47.76	0	1.65	7.80
J23A1-5	0.26	0	2.02	1.13	0.39	31.94	0.19	1.17	62.92
J23A1-6	1.38	0	1.35	1.13	0.29	21.23	0	0.59	9.17
J23A1-7	0	0	0.45	0.55	0.07	8.61	0	0	3.87
J23A1-8	0.17	0	1.69	1.14	0.41	32.83	0	0.82	32.68
J23A1-9	0	9.11	1.97	0.95	0.21	18.87	0	0.68	8.13
J23A1-10	0	0	1.88	0.73	0.36	23.63	0.16	0.63	23.05
J23A1-11	0.62	0	5.69	2.01	0.62	17.47	0.49	1.09	6.83
J23A1-12	2.92	2.53	4.22	2.49	0.69	18.44	0.61	1.06	127.08
J23A1-13	0.45	9.45	5.93	2.57	0.48	17.50	0.28	1.09	305.13
J23A1-14	0.7	2.02	3.93	1.96	0.45	14.16	0.25	0.72	148.98
J23A1-15	2.31	5.52	4.14	1.84	0.42	13.37	0.29	0.57	33.8
J23A1-16	0.01	0	2.53	1.53	0.28	6.45	0.19	0.39	12.39
J23A1-17	0.4	1.87	1.67	2.84	0.64	18.07	0.58	0.56	9.88
J23A1-18	3.02	2.18	2.23	3.19	0.97	18.08	0.93	0.99	7.25
J23A1-19	1.13	1.6	2.82	4.82	0.76	16.88	0.53	0.73	57.96
J23A1-20	1.39	4.69	4.25	5.02	0.85	18.18	0.72	0.71	65.91
J23A1-21	0.46	0.63	2.7	2.59	0.72	12.88	0.43	0.75	5.88
J23A1-22	0.56	0.89	2.77	2.68	0.7	14.59	0.43	0.81	11.4
J23A1-23	1.68	4.47	2.73	3.19	0.82	14.40	0.59	0.92	7.32
J23A1-24	0.6	0.86	2.86	2.80	0.76	13.16	0.56	0.84	86.03

Table 15. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in μg/L for site K22 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
K22A1-1	0.03	0.24	4.98	0.09	0	8.56	1.4	27.24	580.03
K22A1-2	0.12	0.61	5.28	0.06	5.29	13.19	0.29	186.36	488.14
K22A1-3	0	0.14	11.76	0.08	1.01	10.2	0.12	30.69	1574.77
K22A1-4	0.29	0.4	45.7	0.1	0.09	44.29	0.78	30.44	4788.51
K22A1-5	0.43	0.34	34.97	0.13	0.73	58.36	1.07	29.69	2864.74
K22A1-6	0.12	0.22	21.1	0.14	0.17	47.38	1.04	35.21	1701.47
K22A1-7	0.57	0.17	19.31	0.23	0.16	49.93	1	26.19	1531
K22A1-8	0.46	0.26	22.88	0.12	0	81.51	1.66	95.58	1804.1
K22A1-9	0.83	0.31	17.96	0.16	0.28	89.96	1.18	54.32	1356.96
K22A1-10	0.80	0.45	16.72	0.11	0.05	101.82	1.55	53.44	1271.44
K22A1-11	5.20	0.37	16.5	0.17	0.17	95.33	1.61	99.65	1089.24
K22A1-12	2.77	0.27	17.16	0.38	0.09	89.39	4.21	62.68	1122.21
K22A1-13	2.29	0.15	10.21	0.43	0.1	41.65	2.81	28.79	764.44
K22A1-14	2.98	0.35	16.73	0.37	0.08	78.58	3.8	60.56	1126.39
K22A1-15	2.97	0.09	10.69	0.36	0.08	38.75	2.75	141	665.05
K22A1-16	2.14	0.07	11.61	0.27	0.29	36.13	2.47	36.9	766.88
K22A1-17	4.68	0.24	16.36	0.09	0.01	42.24	1.83	61.04	1064.22
K22A1-18	0.78	0.22	11.73	0.13	0.17	50.11	1.16	121.42	741.77
K22A1-19	0.81	0.15	9.14	0.12	0.07	33.74	1.19	24.72	634.3
K22A1-20	2.18	0.38	15.16	0.24	0.17	90.02	4.11	77.67	1063.68
K22A1-21	0.56	0.2	8.69	0.09	0.02	40.84	0.43	18	550.14
K22A1-22	0.61	0.22	8.86	0.12	0.28	47.76	0.66	22.24	567.1
K22A1-23	0.62	0.1	7.89	0.08	0.07	43.3	0.97	20.64	504.6
K22A1-24	0.66	0.18	9.32	0.14	0.1	47.23	0.73	17.88	730.32

Table 16. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site K22 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
K22A1-1	2.04	0	0.03	0.61	0.08	5.52	0	1.12	268.01
K22A1-2	7.05	0	0.12	0.50	0.21	11.55	0	2.80	6.55
K22A1-3	5.51	0	0	0.49	0.09	18.98	0	0.03	12.75
K22A1-4	6.78	0	0.29	0.64	0.34	77.49	0	0.53	6.97
K22A1-5	11	0	0.43	0.68	0.22	48.12	0	0.28	13.46
K22A1-6	9.94	0.2	0.12	0.58	0.18	27.05	0	0.24	53.69
K22A1-7	12.23	0	0.57	0.47	0.14	24.30	0	0.08	34.57
K22A1-8	12.69	0	0.46	0.42	0.09	27.75	0	0.18	16.59
K22A1-9	13.73	13.85	0.83	0.53	0.04	20.25	0	0.24	56.69
K22A1-10	14.3	0	0.8	0.43	0.09	19.49	0	0.22	20.16
K22A1-11	7.16	0	5.2	1.43	0.26	18.73	0.12	0.70	13.47
K22A1-12	6.06	3.43	2.77	1.98	0.35	19.22	0.24	0.52	62.89
K22A1-13	3.45	3.48	2.29	1.74	0.18	12.39	0.22	0.34	26.90
K22A1-14	2.15	0.3	2.98	1.95	0.28	19.69	0.62	0.63	84.55
K22A1-15	3.05	2.2	2.97	1.57	0.15	11.56	0.12	0.36	36.82
K22A1-16	0.63	3.59	2.14	1.52	0.18	12.94	0.37	0.36	17.02
K22A1-17	3.22	0.63	4.68	2.69	0.48	17.89	0.40	0.59	25.98
K22A1-18	2.69	5.95	0.78	2.25	0.55	12.85	0.29	0.49	28.75
K22A1-19	14.95	3.72	0.81	2.57	0.46	10.93	0.34	0.38	35.52
K22A1-20	29.94	4.88	2.18	2.95	0.9	19.06	0.87	0.99	21.32
K22A1-21	1.55	2.36	0.56	2.16	0.46	10.82	0.28	0.53	24.15
K22A1-22	2.08	0.05	0.61	2.14	0.44	9.90	0.30	0.44	26.41
K22A1-23	1.36	7.76	0.62	2.53	0.44	8.56	0.26	0.44	18.75
K22A1-24	1.45	0.67	0.66	2.31	0.5	28.94	0.49	0.70	181.09

Table 17. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in ug/L for site N23 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
N23A1-1	0	0.33	4.62	0.06	0	4.15	0.73	79.3	229.75
N23A1-2	0	0.47	2.98	0.08	3.4	6.96	0.42	38.94	315.02
N23A1-3	0.72	0.24	10.21	0.11	1.78	6.99	5.35	18.76	793.15
N23A1-4	0.73	0.81	20.99	0.1	0.42	54.54	2.32	97.95	1174.76
N23A1-5	0.59	0.7	13.04	0.09	0.17	83.24	2.58	122.43	723.27
N23A1-6	0.75	0.67	14.37	0.15	0.44	118.68	3.55	370.96	1011.49
N23A1-7	1.48	0.24	5.5	0.12	0.08	61.7	1.75	76.73	329.44
N23A1-8	0.51	0.52	10.37	0.02	0	90.86	2.37	153.45	818.46
N23A1-9	0.54	0.6	11.44	0.01	0	96.33	2.41	141.47	642.84
N23A1-10	1.12	0.67	14.63	0.2	0.02	133.74	3.9	184.36	778.42
N23A1-11	5.24	0.44	12	0.1	0.57	99.14	2.72	163.17	597.51
N23A1-12	2.60	0.35	11.56	9.36	0.3	77.26	4.08	146.09	712.33
N23A1-13	2.71	0.25	17.55	0.26	0.12	50.53	3.52	66.4	1151.6
N23A1-14	4.44	0.51	22.31	0.3	0.18	66.03	4.93	133.83	1397.03
N23A1-15	3.01	0.24	15.43	0.28	0.1	48.51	3.41	150.53	926.03
N23A1-16	2.44	0.15	14.66	0.21	0.3	26.11	2.96	44.43	907.34
N23A1-17	0.53	0.28	18.79	0	0.01	31.99	0.8	61.03	1069.48
N23A1-18	0.63	0.21	15.65	0	0.11	37.06	1.29	213.02	1090
N23A1-19	0.97	0.4	69.15	0.08	0.38	76.59	2.53	154.67	3507.18
N23A1-20	1.40	0.22	43.87	0.14	0.38	44.57	1.93	153.14	2033.05
N23A1-21	0.55	0.36	15.1	0	0.04	48.49	0.88	64.61	872.89
N23A1-22	0.61	0.28	12.86	0.01	0.38	46.84	0.99	64.53	770.35
N23A1-23	0.92	0.27	11.04	0.03	0.15	43.01	1.48	57.86	634.48
N23A1-24	1.02	0.19	12.24	0.03	0.08	41.29	1.11	46.83	638.17

Table 18. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site N23 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
N23A1-1	7.96	0	0	0.48	0.06	1.65	0	0.09	13.80
N23A1-2	1.7	0	0	0.38	0.09	1.60	0	0	18.51
N23A1-3	17.45	0	0.72	0.44	0.08	5.05	0	0	14.62
N23A1-4	15.74	0	0.73	0.58	0.32	10.24	0.21	0	18.80
N23A1-5	10.33	0	0.59	0.58	0.24	6.05	0.47	0	9.79
N23A1-6	17.74	0	0.75	0.88	0.35	6.50	0	0	26.96
N23A1-7	5.51	0	1.48	0.32	0.17	2.53	0	0	11.44
N23A1-8	5.5	2.53	0.51	0.29	0.11	3.56	0.29	0	29.76
N23A1-9	6.83	0	0.54	0.48	0.1	4.02	0.11	0	11.28
N23A1-10	9.22	0	1.12	0.28	0.15	5.18	0.46	0	73.53
N23A1-11	7.04	0	5.24	1.34	0.28	4.92	0.89	0.26	27.82
N23A1-12	8.24	0.36	2.6	1.89	0.31	4.88	0.48	0.20	127.64
N23A1-13	3.25	4.41	2.71	1.56	0.37	8.15	0.34	0.19	38.57
N23A1-14	5.92	5.54	4.44	1.85	0.38	10.70	0.49	0.22	47.51
N23A1-15	2.25	4.21	3.01	1.58	0.33	7.58	0.33	0.19	21.13
N23A1-16	2.14	2.91	2.44	1.39	0.24	7.04	0	0.14	29.18
N23A1-17	1.69	0.07	0.53	2.37	0.61	9.03	0.42	0.20	16.09
N23A1-18	2.48	0.25	0.63	2.50	0.66	7.34	0.39	0.13	23.43
N23A1-19	190.24	2.1	0.97	2.81	2.12	36.99	0.84	0.25	35.93
N23A1-20	110.56	5.14	1.4	2.36	1.25	21.93	0.55	0.22	206.02
N23A1-21	5.53	0.15	0.55	2.03	0.61	7.21	0.41	0.18	70.73
N23A1-22	4.12	0.12	0.61	2.07	0.55	5.83	0.42	0.14	23.98
N23A1-23	3.15	20.94	0.92	2.31	0.51	4.78	0.47	0.13	31.03
N23A1-24	2.83	1.3	1.02	2.24	0.53	5.43	0.53	0.19	104.25

Table 19. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in μg/L for site O22 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
O22A1-1	0	0.09	48.33	0.07	0	5.38	1.47	0	107.91
O22A1-2	0	0.08	42.41	0.05	0.56	6.86	0.16	23.01	170.21
O22A1-3	0.13	0.05	38.76	0.1	0.93	5.54	0.31	4.26	664.05
O22A1-4	0.33	0.05	31.69	0.09	0.68	7.6	3.07	9.63	565.3
O22A1-5	0	0.08	22.49	0.08	0.71	7.07	0.59	13.37	395.41
O22A1-6	0.22	0.01	37.15	0.09	0.5	3.69	0.48	28.56	340.34
O22A1-7	0	0	10.72	0.06	0.14	2.41	0.54	0.5	284.62
O22A1-8	0.68	0.07	23.66	0	0.56	10.48	0.12	22.91	517.57
O22A1-9	0.16	0	10.93	0.02	0.16	5.1	0.8	25.14	295.33
O22A1-10	0.20	0.05	20.68	0.17	0.27	10.53	0.22	18.44	348.97
O22A1-11	4.66	0.04	12.58	0.12	0.11	6.64	0.21	126.38	233.79
O22A1-12	1.68	0.07	19.69	0.27	0.15	9.48	2.63	8.31	256.37
O22A1-13	1.65	0.04	11.05	0.24	0.1	7.85	2.33	7.12	172.39
O22A1-14	2.10	0.04	15.24	0.28	0.21	10.07	2.47	18.64	166.64
O22A1-15	2.15	0.01	13.44	0.26	0.19	6.85	2.43	72.36	195.18
O22A1-16	1.74	0.03	52.55	0.26	0.17	7.69	2.33	7.91	174.87
O22A1-17	0.65	0.07	36.31	0	0.07	7.01	0.1	5.97	130.37
O22A1-18	0.21	0.03	25.12	0	0.19	9.03	0.49	18.58	161.71
O22A1-19	0.33	0	26.29	0	0.23	8.4	1.13	207.59	114.11
O22A1-20	0.48	0	23.79	0.01	0.15	8.81	1.67	16.96	137.06
O22A1-21	0.13	0	41.44	0	0.12	8.47	0	1.28	100.55
O22A1-22	0.20	0.04	34.13	0	0.74	10.44	14.56	1.98	93.1
O22A1-23	41.71	0.03	31.28	1	0.21	16.34	0.73	1.69	108.7
O22A1-24	0.50	0	32.69	0.03	0.19	21.7	1.38	4.1	112.3

Table 20. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site O22 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
O22A1-1	2.31	0	0	0.45	0.08	9.66	0	0	34.03
O22A1-2	1.05	0	0	0.32	0.06	8.46	0	0	22.39
O22A1-3	5.97	0	0.13	0.40	0.14	16.69	0	0	6.88
O22A1-4	4.87	0	0.33	0.39	0.11	14.26	0	0	8.19
O22A1-5	3.15	0	0	0.36	0.08	9.58	0	0	42.15
O22A1-6	2.07	0	0.22	0.37	0.13	10.45	0	0	9.26
O22A1-7	2.3	0	0	0.32	0.08	6.53	0	0	14.87
O22A1-8	4.21	0	0.68	3.03	0.26	14.24	0	0	23.15
O22A1-9	1.92	1.98	0.16	2.86	0.16	7.28	0.06	0	58.85
O22A1-10	2.75	0.81	0.2	2.84	0.21	11.79	0.05	0	9.51
O22A1-11	1.46	0	4.66	1.05	0.21	6.75	0	0.09	13.62
O22A1-12	1.65	0	1.68	1.65	0.25	9.38	0	0.09	35.69
O22A1-13	1.31	0.9	1.65	1.59	0.17	7.16	0	0.12	25.31
O22A1-14	1.51	0	2.1	1.41	0.16	6.76	0	0.09	21.37
O22A1-15	1.36	2.89	2.15	1.43	0.14	6.32	0.15	0.10	24.81
O22A1-16	0.72	0	1.74	1.37	0.17	7.81	0.08	0.10	30.75
O22A1-17	2.38	1.25	0.65	2.16	0.78	7.21	0.08	0.12	65.52
O22A1-18	1.02	0.71	0.21	2.13	1.03	7.67	0.07	0.07	7.37
O22A1-19	3.09	2.61	0.33	2.11	0.49	5.78	0.21	0.06	29.26
O22A1-20	3.23	4.14	0.48	2.20	0.76	10.12	0.20	0.05	62.72
O22A1-21	0.67	0.04	0.13	1.98	0.69	6.13	0.13	0.09	31.82
O22A1-22	1.09	0.39	0.2	2.10	0.8	5.97	0.30	0.09	33.94
O22A1-23	0.75	13.54	41.71	2.12	0.9	6.90	0.18	0.10	41.95
O22A1-24	0.8	3.04	0.5	2.19	0.89	7.61	0.20	0.14	47.95

Table 21. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site P25 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
P25A1-1	0.48	0.35	2.09	0.16	0	7.42	3.87	38.02	167.2
P25A1-2	0.06	0.26	2.14	0.06	10.56	14.77	0.85	47.89	110.56
P25A1-3	1.02	1.14	5.33	0.09	0.93	87.37	2.92	156.12	482.57
P25A1-4	2.22	0.92	7.45	0.14	0.66	124.42	3.62	164.07	365.45
P25A1-5	0.32	0.42	2.75	0.07	0.11	78.86	2.04	102.16	161.09
P25A1-6	0.41	0.57	4.15	0.08	0.12	91.56	2.42	122.96	307.22
P25A1-7	0.06	0.07	1.78	0.08	0.16	35.2	1.23	47.39	170.77
P25A1-8	0.55	0.6	7.22	0	0.07	106.94	2.06	106.56	664.06
P25A1-9	0.37	0.25	3.5	0.03	0.07	62.01	1.96	69.99	298.15
P25A1-10	0.84	0.17	9.44	0.2	0.15	52.72	1.11	68.57	369.47
P25A1-11	4.47	0.21	5.33	0.11	0.06	57.71	2.02	59.49	344.4
P25A1-12	2.20	0.15	5.05	0.27	0.17	53.08	3.33	66.18	389.75
P25A1-13	23.61	10.52	237.02	2.69	4.83	52.80	49.01	1769.08	20237.92
P25A1-14	2.70	0.36	7.87	0.34	0.17	51.7	4.11	120.48	845.59
P25A1-15	2.06	0.17	5.3	0.25	0.11	45.41	3.24	75.79	555.12
P25A1-16	1.98	0.12	8.05	0.22	0.08	23.92	2.61	47.1	830.46
P25A1-17	0.37	0.14	11.68	0	0.02	30.79	0.67	28.51	928.38
P25A1-18	0.49	0.12	6.56	0	0.62	31.12	0.64	66.41	638.55
P25A1-19	0.57	0.23	14.74	0.08	0.46	11.38	1.15	70.14	1875.01
P25A1-20	1.29	0.31	12.07	0.1	0.23	126.1	2.66	113.34	637.15
P25A1-21	0.21	0.04	2.4	0	0	25.13	0	17.4	207
P25A1-22	0.49	0.38	7.06	0.01	0.21	49.33	0.97	47.56	521.06
P25A1-23	0.74	0.36	6.91	0.03	0.11	70.08	1.55	56.53	535.27
P25A1-24	2.21	0.2	12.76	0.23	0.18	73.78	3.55	66.61	653.77

Table 22. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site P25 weekly wetting and drying experiment for sampling intervals 1-24.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
P25A1-1	3.08	7.02	0.48	0.50	0.02	1.39	0	0.53	51.09
P25A1-2	0.63	0	0.06	0.45	0.04	1.10	0	0	3.37
P25A1-3	1.66	0	1.02	0.59	0.19	3.58	1.38	1.27	13.95
P25A1-4	4.45	0	2.22	0.64	0.1	4.59	2.12	0.67	23.65
P25A1-5	1.04	0	0.32	0.57	0.06	1.56	0.87	0.28	6.57
P25A1-6	2.05	0	0.41	0.57	0.13	2.93	1.00	0.44	9.00
P25A1-7	2.32	0	0.06	0.40	0.06	1.54	0.03	0	6.83
P25A1-8	1.97	0.05	0.55	2.82	0.21	6.65	1.43	0.42	3.41
P25A1-9	2.4	0.02	0.37	2.68	0.12	2.87	0.76	0.01	13.13
P25A1-10	3.62	1.48	0.84	2.67	0.13	4.63	0.62	0.12	324.05
P25A1-11	2.4	5.04	4.47	1.30	0.11	2.77	1.14	0.26	33.17
P25A1-12	1.8	0.15	2.2	1.89	0.14	2.91	0.67	0.22	44.00
P25A1-13	45.02	219.49	23.61	56.76	14.97	203.20	72.37	9.26	871.25
P25A1-14	3.19	2.33	2.7	1.85	0.17	6.25	0.70	0.34	35.37
P25A1-15	1.69	2.08	2.06	1.55	0.15	4.64	0.28	0.30	37.16
P25A1-16	1.23	0	1.98	1.53	0.15	7.39	0.25	0.23	11.97
P25A1-17	1.37	0.19	0.37	2.13	0.45	9.27	0.35	0.21	110.37
P25A1-18	1.25	1.45	0.49	2.03	0.45	5.77	0.50	0.28	70.75
P25A1-19	34.58	4.03	0.57	2.70	1.3	39.73	0.75	0.81	53.64
P25A1-20	37.42	7.47	1.29	2.24	0.8	10.24	1.10	0.69	28.93
P25A1-21	0.43	0	0.21	1.83	0.42	1.52	0.53	0.16	6.03
P25A1-22	1.6	0.34	0.49	2.13	0.46	4.93	0.97	0.37	23.27
P25A1-23	1.69	8.43	0.74	2.30	0.53	5.09	1.11	0.41	39.46
P25A1-24	2.13	2.92	2.21	2.10	0.52	6.77	1.19	0.39	77.23

Table 23. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in μg/L for site J19 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
J19B1-1	2.17	0.3	35.51	0.35	0.01	59.95	2.14	42.68	549.92
J19B1-2	5.32	0.7	70.18	1.33	0.73	403.78	5.72	39.45	4318.74
J19B1-3	1.42	0.25	20.95	0.73	0.63	73.65	1.37	20.29	1323.98
J19B1-4	2.40	0.05	23.52	0.79	0.44	136.89	2.1	82.59	1615.5
J19B1-5	1.83	0	19.64	0.44	0.11	126.06	1.92	58.15	1202.65
J19B1-6	7.24	0.21	25.52	0.72	0.23	104.78	1.68	43.71	1128.39
J19B1-7	5.61	0.13	25.49	0.63	0.09	85.96	1.45	9.69	1333.82
J19B1-8	5.22	0.08	26.44	0.59	0.06	52.17	0.8	20.53	1373.65
J19B1-9	5.52	0.04	27.09	0.46	0.08	41.44	0.6	7.72	1036.14
J19B1-10	0.95	0.13	42.83	0.43	0.34	61.63	1.37	33.62	1485.46
J19B1-11	2.20	0.04	28.35	0.3	0.76	44.61	0.69	26.85	1042.36
J19B1-12	0.84	0.04	27.71	0.22	0.03	36.75	0.55	9.91	788.42
J19B1-13	1.16	0.05	24.01	0.28	0.32	40.28	1.05	7.59	809.93

Table 24. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in μg/L for site J19 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
J19B1-1	11.6	0	2.17	0.37	0.11	4.16	0	0	52.88
J19B1-2	127.51	0	5.32	0.80	0.69	26.75	0.73	0.14	198.22
J19B1-3	54.44	0	1.42	0.31	0.09	8.64	0	0	91.11
J19B1-4	64.99	5.84	2.4	1.08	0.23	9.72	0	0	110.24
J19B1-5	20.7	0	1.83	0.43	0.07	6.03	0	0	85.95
J19B1-6	22.96	1.96	7.24	2.16	0.36	7.49	0	0.21	137.94
J19B1-7	14.82	0	5.61	1.53	0.27	8.21	0	0.17	74.93
J19B1-8	14.6	0	5.22	1.43	0.22	8.00	0	0.10	112.44
J19B1-9	4.34	8.35	5.52	1.26	0.32	6.66	0.13	0.10	277.03
J19B1-10	11.67	1.52	0.95	2.96	0.98	10.59	0.40	0.22	65.23
J19B1-11	3.66	0.56	2.2	2.63	0.57	7.00	0.18	0.17	72.98
J19B1-12	3.38	0.97	0.84	2.32	0.52	5.16	0.26	0.10	127.01
J19B1-13	4.48	0.97	1.16	2.43	0.51	6.12	0.36	0.09	56.03

Table 25. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J23 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
J23B1-1	0.87	0.3	2.28	0.11	0	4.37	0.27	8.99	461.81
J23B1-2	2.24	0.7	16.51	0.47	7.48	36.09	1.06	15.96	2993.21
J23B1-3	1.93	0.25	11.85	0.82	1.69	32.16	1.12	10.36	2020.13
J23B1-4	1.08	0.05	6.47	0.97	0.64	13.16	1.1	6.16	1067.09
J23B1-5	1.05	0	8.41	0.56	0.32	12.96	0.76	96.83	1392.28
J23B1-6	4.81	0.07	15.14	0.97	0.26	13.65	0.93	14.11	1867.14
J23B1-7	4.97	0.07	6.54	0.59	0.31	7.01	51.24	28.5	902
J23B1-8	4.94	0.03	6.44	0.55	0.11	5.18	0.4	54.83	952.18
J23B1-9	6.13	0.05	8.99	0.8	0.32	11.18	0.18	3.6	1139.34
J23B1-10	0.83	0.02	6.81	0.43	0.59	7.93	0.09	5.95	788.84
J23B1-11	1.24	0.03	8.8	0.6	0.36	7.81	0.13	14.94	1205.11
J23B1-12	0.70	0.03	7.51	0.57	0.25	11.31	0	26.05	1117
J23B1-13	1.26	0.07	17.04	1.22	0.64	13.24	1.15	4.82	2496.36

Table 26. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in μg/L for site J23 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	**Mn**	**Ni**	**Pb**	**Se**	**Sc**	**Sr**	**Ti**	**V**	**Zn**
J23B1-1	0	0	0.87	0.54	0.07	6.62	0	2.09	3.28
J23B1-2	0.55	0	2.24	1.29	0.31	46.84	0	2.05	1.81
J23B1-3	0.58	0	1.93	0.91	0.19	33.24	0	0.8	15.15
J23B1-4	1.99	0	1.08	1.27	0.15	15.73	0	0.22	39.33
J23B1-5	0	19.28	1.05	0.67	0.27	22.04	0	0.08	9.08
J23B1-6	2.38	7.81	4.81	1.73	0.53	33.14	0.11	0.53	42.59
J23B1-7	0.32	107.76	4.97	1.50	0.5	15.60	0.12	0.37	146.35
J23B1-8	0.21	0.2	4.94	1.48	0.42	13.01	0.08	0.3	15.14
J23B1-9	0.11	0	6.13	1.29	1.07	22.16	0.94	0.34	128.57
J23B1-10	1.06	1.51	0.83	2.21	0.89	15.12	0.47	0.29	69.12
J23B1-11	0.43	0.83	1.24	2.47	0.82	20.83	0.50	0.31	88.67
J23B1-12	0.14	0.45	0.7	2.22	0.75	18.09	0.48	0.27	4.32
J23B1-13	0.25	4.64	1.26	2.58	1.24	9.76	0.60	0.44	56.29

Table 27. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site K22 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
K22B1-1	0.11	0.17	3.93	0.07	0	7.68	0.2	50.44	390.66
K22B1-2	2.29	0.68	41.23	0.15	0.43	58.01	1.43	74.56	3599.22
K22B1-3	0.09	0.26	21.04	0.11	0.82	40.59	0.76	84.76	2367.23
K22B1-4	0.02	0.09	18.57	0.19	0.15	18.88	1.33	127.23	1970.16
K22B1-5	0.27	0.07	20.19	0.24	0.05	15.39	0	25.91	4191.98
K22B1-6	3.73	0.12	16.83	0.39	0.1	13.86	0.02	12.82	3789.56
K22B1-7	3.72	0.07	14.58	0.28	0.05	10.08	0.09	15.85	1728.47
K22B1-8	4.45	0.05	12.79	0.46	0.16	8.9	0.07	8.01	1492.82
K22B1-9	4.24	0.07	12.83	0.31	0.09	9.31	0	6.98	1401.47
K22B1-10	0.36	0.07	28.63	0.35	0.17	19.93	0.35	13.83	2092.61
K22B1-11	0.79	0.05	23.92	0.23	0.09	17.63	0.35	27.03	1590.43
K22B1-12	0.30	0.03	16.86	0.19	0.03	15.48	0.73	14.35	1107.34
K22B1-13	0.86	0.23	24.52	0.33	0.19	44.71	1.26	22.45	1597.87

Table 28. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site K22 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
K22B1-1	3.79	0	0.11	0.42	0.08	5.27	0	0.82	9.15
K22B1-2	3.11	0	2.29	0.64	0.3	55.39	0	0.89	11.23
K22B1-3	3.77	0	0.09	0.53	0.18	33.74	0	0.55	7.89
K22B1-4	11.35	8.69	0.02	0.9	0.17	31.48	0	0	26.02
K22B1-5	14.72	0	0.27	0.29	0.06	61.38	0	0	40.46
K22B1-6	8.28	0	3.73	1.45	0.43	58.59	0.65	0.29	47.36
K22B1-7	1.42	0	3.72	1.22	0.28	26.70	0	0.21	114.89
K22B1-8	1.07	0.31	4.45	1.26	0.22	24.48	0	0.22	162.98
K22B1-9	1.45	0	4.24	1.16	0.23	21.47	0.33	0.18	82.04
K22B1-10	5.64	0.27	0.36	2.27	1.76	37.95	0.68	0.52	85.91
K22B1-11	0.86	2.37	0.79	2.5	0.97	29.25	0.46	0.33	29.32
K22B1-12	0.54	0.1	0.3	2.22	0.63	19.17	0.31	0.26	17.08
K22B1-13	1.92	2.22	0.86	2.33	0.85	7.88	0.41	0.48	86.64

Table 29. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site N23 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
N23B1-1	0	0.26	2.57	0.1	0	3.13	0.25	91.07	208.19
N23B1-2	0.09	0.58	11.6	0.13	0.68	22.56	0.85	61.86	886.4
N23B1-3	0	0.47	12.06	0.08	0.6	34.7	1.08	61.55	779.78
N23B1-4	0.68	0.28	12.12	0.12	0.4	49.08	2.26	79.97	735.22
N23B1-5	0.64	0.48	23.53	0.06	0.1	86.22	3.78	122.11	944.92
N23B1-6	4.08	0.43	32.24	0.1	0.06	64.25	1.57	79.23	1911.93
N23B1-7	4.56	0.31	27.59	0.14	0.15	48.63	1.65	90.4	1906.97
N23B1-8	4.66	0.27	30.54	0.11	0.12	43.23	1.02	73.09	1804.8
N23B1-9	4.36	0.37	22.35	0.09	0.03	46.64	1.28	58.09	1290.41
N23B1-10	0.51	0.4	19.3	0	0.36	42.78	1.72	55.07	1167.31
N23B1-11	1.31	0.33	17.12	0.01	0.07	49	1.3	87.18	1002.97
N23B1-12	0.92	0.56	24.13	0.02	0.08	97.03	2.14	121.25	1350.39
N23B1-13	0.86	0.51	16.38	0.05	0.09	71.11	1.89	87.51	990.55

Table 30. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site N23 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
N23B1-1	5.7	0	0	0.38	0.07	1.20	0	0.05	1.36
N23B1-2	3.01	0	0.09	0.41	0.18	6.35	0	0.02	7.36
N23B1-3	4.54	0	0	0.44	0.18	5.89	0	0	7.30
N23B1-4	7.39	2.92	0.68	0.91	0.18	5.75	0	0	18.29
N23B1-5	14.38	2.21	0.64	3.04	0.5	8.56	0.69	0	20.31
N23B1-6	9.1	0	4.08	1.67	0.63	15.56	0.49	0.25	107.6
N23B1-7	17.71	0.92	4.56	1.52	0.42	14.30	0.17	0.25	27.83
N23B1-8	4.51	0	4.66	1.34	0.51	14.42	0.39	0.18	37.20
N23B1-9	5.16	0	4.36	1.25	0.39	10.78	0.49	0.19	56.14
N23B1-10	10.07	0.96	0.51	2.30	0.71	9.95	0.42	0.23	103.85
N23B1-11	6.37	2.56	1.31	2.72	0.58	7.63	0.54	0.27	28.27
N23B1-12	11.73	0.68	0.92	2.31	0.96	11.27	0.94	0.27	34.28
N23B1-13	8.73	0.6	0.86	2.41	0.58	8.65	0.55	0.22	23.48

Table 31. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site O22 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
O22B1-1	0	0.06	55.39	0.07	0	14.52	0.23	6.32	121.15
O22B1-2	2.57	0.13	66.41	0.18	1.15	9.09	0.62	70.57	719.33
O22B1-3	0.22	0.02	17.85	0.07	0.78	4.84	0.4	9.86	563.77
O22B1-4	0.43	0.02	10.94	0.1	0.56	4.33	0.51	18.3	366.3
O22B1-5	0.07	0.07	14.61	0	0.36	8.11	0.03	15.72	636.44
O22B1-6	3.89	0.11	15.66	0.11	0.39	8.51	0.61	16.62	583.32
O22B1-7	4.12	0.09	13.14	0.11	0.28	6.28	0.72	8.49	444.17
O22B1-8	3.89	0.04	9.63	0.11	0.26	5.19	0.15	19.85	410.96
O22B1-9	4.07	0.05	55.2	0.14	0.12	6.46	0.33	5.08	237.67
O22B1-10	0.48	0.03	15.32	0	1.14	5.43	0.78	8.84	293.44
O22B1-11	0.53	0.08	10.68	0	0.29	4.82	0.26	15.78	313.41
O22B1-12	0.42	0.03	8.67	0	0.21	5.28	0.46	6.67	304.02
O22B1-13	0.35	0.08	9.47	0	0.96	6.18	0.06	2.63	248.27

Table 32. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site O22 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
O22B1-1	2.37	0	0	0.36	0.09	10.92	0	0	1.66
O22B1-2	2.74	0	2.57	0.32	0.14	19.93	0	0.01	4.53
O22B1-3	3.33	0	0.22	0.35	0.13	13.21	0	0	22.28
O22B1-4	2.02	0	0.43	0.78	0.13	8.61	0	0	16.46
O22B1-5	3.15	0.13	0.07	2.77	0.24	14.29	0.05	0	63.48
O22B1-6	3.26	0.77	3.89	1.38	0.43	13.73	0.05	0.14	68.25
O22B1-7	2.02	0	4.12	1.30	0.31	12.24	0	0.11	26.33
O22B1-8	0.79	0	3.89	1.17	0.24	11.38	0	0.13	8.08
O22B1-9	1.22	0	4.07	1.05	0.18	10.11	0	0.11	18.25
O22B1-10	1.59	1.14	0.48	2.25	1.81	10.49	0.01	0.11	131.75
O22B1-11	0.81	0.92	0.53	2.61	1.61	1.44	0.18	0.13	6.49
O22B1-12	0.46	0.79	0.42	2.08	1.83	0.74	0.14	0.18	116.57
O22B1-13	0.47	0.17	0.35	2.25	1.43	0.45	0.16	0.08	11.25

Table 33. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site P25 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
P25B1-1	0	0.22	1.53	0.09	0	6.79	1.28	187.81	187.61
P25B1-2	1.86	1.05	4.46	0.12	0.84	73.89	2.73	232.17	328.8
P25B1-3	0.39	0.81	6.06	0.09	0.41	84.81	2.36	124.84	415.12
P25B1-4	1.12	0.92	4.31	0.13	0.2	130.73	3.87	179.23	332.87
P25B1-5	1.99	0.75	4.47	0.06	0.19	147.45	4.03	198.78	303.69
P25B1-6	4.79	0.4	9.03	0.09	0.1	83.6	2.59	147.06	925.3
P25B1-7	4.85	0.22	22.37	0.22	0.12	37.58	1.01	56.12	2181.7
P25B1-8	4.19	0.15	14.23	0.14	0.16	27.01	0.34	56.32	1378.07
P25B1-9	3.80	0.15	6.98	0.09	0.09	21.21	0.07	27.42	658.2
P25B1-10	1.43	0.12	4.74	0.01	0.93	31	0.38	37.82	433.53
P25B1-11	0.62	0.04	4.09	0	0.09	28.91	0.25	29.45	364.06
P25B1-12	0.44	0.18	7.63	0	0.04	47.87	0.88	71.94	675.98
P25B1-13	0.70	0.2	8.71	0	0.21	29.97	0.69	38.93	811.85

Table 34. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site P25 bimonthly wetting and drying experiment for sampling intervals 1-13.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
P25B1-1	5.14	0	0	0.47	0.06	1.26	0	0	17.98
P25B1-2	1.06	0	1.86	0.39	0.18	2.84	0.93	0.01	11.48
P25B1-3	3.79	0	0.39	0.63	0.14	4.25	0.72	0	11.48
P25B1-4	7.94	0	1.12	1.00	0.13	3.54	1.58	0	37.11
P25B1-5	7.26	0.81	1.99	2.93	0.19	3.38	2.15	0	25.46
P25B1-6	10.78	0	4.79	1.64	0.19	7.03	0.85	0.14	27.95
P25B1-7	13.23	0	4.85	1.54	0.37	21.29	0.28	0.11	25.95
P25B1-8	4.09	0	4.19	1.38	0.34	13.76	0.13	0.13	60.5
P25B1-9	1.78	0	3.8	1.12	0.2	6.29	0.54	0.11	109.48
P25B1-10	1.11	6.45	1.43	2.10	0.51	3.99	0.53	0.11	331.4
P25B1-11	0.5	1.23	0.62	2.46	0.48	3.17	0.27	0.13	42.60
P25B1-12	1.24	0.1	0.44	2.09	0.35	6.55	0.52	0.18	6.98
P25B1-13	3.48	0.57	0.7	2.15	0.37	8.10	0.53	0.08	16.46

Table 35. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J19 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
J19D-1	6.57	0.14	77.2	0.76	0.14	208.93	10.23	102.58	920.14
J19D-2	9.46	0.23	59.39	0.94	0.12	345.87	6.61	61.18	913.95
J19D-3	6.84	0.14	61.79	1.3	0.12	252.95	5.01	45.31	1935.83
J19D-4	5.53	0.22	61.23	1.1	0.31	244.2	3.73	33.61	2050.54
J19D-5	6.18	0.23	52.18	1.34	0.48	312.54	5.6	37.55	2177.72
J19D-6	6.25	0.2	40.07	1.1	0.22	311.09	6.42	40.32	1628.45
J19D-7	6.27	0.27	49.15	0.95	0.66	408.56	5.8	46.87	1715.18

Table 36. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site J19 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
J19D-1	11.27	1.04	6.57	2.28	0.72	7.58	1.38	0.29	109.39
J19D-2	20.25	6.08	9.46	2.72	0.57	6.78	0.77	0.31	100.69
J19D-3	28.02	2.3	6.84	2.41	0.82	11.71	0.57	0.21	77.15
J19D-4	35.39	1.02	5.53	3.17	1.05	13.97	0.62	0.26	236.11
J19D-5	41.31	1.14	6.18	2.38	0.84	14.8	0.58	0.25	76.70
J19D-6	36.36	1.4	6.25	2.36	0.67	9.95	0.50	0.18	67.12
J19D-7	32.26	2.4	6.27	2.49	0.73	11.65	0.53	0.18	67.47

Table 37. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in μg/L for site J23 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
J23D-1	7.18	0.98	5.49	0.26	0.13	27.19	0.83	71.88	595.16
J23D-2	8.17	0.09	15.89	1.91	0.08	9.3	0.66	10.31	2280.07
J23D-3	13.24	0.24	54.34	4.12	0.42	21.11	6.42	10.84	6757.07
J23D-4	6.27	0.34	30.16	2.77	0.2	47.3	3.22	5.09	3522.3
J23D-5	4.37	0.11	10.6	1.82	0.22	42.31	2.75	6.06	1540.74
J23D-6	4.08	0.08	9	1.69	0.23	55.76	2.84	1.09	1452.71
J23D-7	3.29	0.11	6.84	1.4	0.99	66.92	2.94	2.46	1012.5

Table 38. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in μg/L for site J23 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
J23D-1	0.44	11.98	7.18	2.26	0.46	10.15	0.49	4.22	15.71
J23D-2	0.54	1.31	8.17	2.67	1.34	42.28	0.45	0.94	15.26
J23D-3	0.51	18.08	13.24	2.79	3.65	143.95	1.01	1.98	15.04
J23D-4	1.44	1.23	6.27	3.39	2.47	73.1	1.02	1.65	36.85
J23D-5	0.84	1.96	4.37	2.64	0.76	26.74	0.39	0.80	21.62
J23D-6	0.8	1.05	4.08	3.04	0.83	23.69	0.47	0.70	9.55
J23D-7	0.53	3.54	3.29	3.15	0.63	17.29	0.34	0.63	7.77

Table 39. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site K22 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
K22D-1	4.59	0.9	12.93	0.08	0.09	37.66	0.81	657.28	922.92
K22D-2	0.59	0.22	13.21	0.05	0.09	10.96	0.09	32.19	2292.55
K22D-3	0.32	0.09	21.45	0.18	0.14	11.14	0	85.94	5712.67
K22D-4	1.16	0.35	32.64	0.56	0.26	59.08	0.63	29.52	8260.7
K22D-5	0.70	0.36	19.46	0.33	0.16	63.7	1.39	48.55	3629.94
K22D-6	0.63	0.46	28.4	0.34	0.15	107.64	1.59	39.73	3366.58
K22D-7	28.75	0.56	24.39	0.29	1.12	116.52	95.17	47.45	2005.42

Table 40. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site K22 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	**Mn**	**Ni**	**Pb**	**Se**	**Sc**	**Sr**	**Ti**	**V**	**Zn**
K22D-1	8.35	3.81	4.59	2.34	0.69	11.77	0.95	3.86	59.62
K22D-2	9.16	1.6	0.59	2.31	1.02	31.87	0.34	0.48	11.56
K22D-3	25.09	0.65	0.32	2.02	2.14	82.88	0.54	0.29	32.35
K22D-4	36.32	0.78	1.16	2.55	3.91	148.77	0.82	0.58	309.67
K22D-5	29.53	1.36	0.7	2.28	1.42	60.47	0.58	0.63	66.88
K22D-6	52.67	2.2	0.63	2.47	1.47	54.93	0.78	0.72	35.24
K22D-7	37.52	483.23	28.75	2.57	1	34.93	0.63	0.70	40.42

Table 41. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site N23 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
N23D-1	2.00	0.97	7.22	0.04	0.03	10.57	0.26	262.47	396.32
N23D-2	0.61	0.66	15.99	0.01	0.12	14.85	2.37	228.02	1847.15
N23D-3	0.53	0.26	30.21	0	0.06	23.25	0.47	61.69	2345.95
N23D-4	1.48	0.72	44.04	0.04	0.19	61.42	2.06	84.89	3037.32
N23D-5	0.95	1.04	30.16	0.12	0.24	96.38	3.65	123.29	1995.82
N23D-6	1.59	1.26	28.16	0.1	0.13	143.63	4.59	166.61	1692.04
N23D-7	1.25	1.28	25.4	0.1	0.35	161.41	4.49	184.99	1512.01

Table 42. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site N23 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
N23D-1	7.77	1.65	2	2.18	0.46	2.4	0.39	0.89	11.64
N23D-2	9.87	2.28	0.61	2.31	1.03	9.71	0.62	0.32	70.41
N23D-3	15.48	0.07	0.53	2.02	1.31	17.98	0.68	0.21	15.69
N23D-4	15.56	1.49	1.48	2.33	1.79	24.32	1.01	0.28	91.65
N23D-5	16.26	3.47	0.95	2.22	1.32	15.95	1.35	0.39	64.13
N23D-6	23.79	1.84	1.59	2.29	1.37	13.3	1.90	0.36	44.34
N23D-7	27.02	4.82	1.25	2.43	1.25	12.05	1.56	0.36	62.85

Table 43. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site O22 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
O22D-1	1.75	0.57	144.23	0.02	0.12	20.79	0	50.21	245.02
O22D-2	0.48	0.08	76.34	0	0.09	12.51	0	23.02	245.48
O22D-3	0.18	0	41.51	0	0.23	2.81	0	10.6	768.2
O22D-4	0.67	0	21.08	0.06	0.32	6.32	0.58	4.56	575.49
O22D-5	0.62	0.03	12.22	0.08	0.95	10.45	1.09	71.32	571.74
O22D-6	0.60	0.04	14.61	0.09	0.39	16.95	1.21	4.06	518.08
O22D-7	0.14	0.06	10.44	0.06	0.75	16.75	0.52	1.63	277.27

Table 44. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site O22 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
O22D-1	4.97	1.06	1.75	2.19	1.58	23.56	0.53	0.73	11.01
O22D-2	1.06	3.27	0.48	2.11	1.13	18.17	0.28	0.27	7.09
O22D-3	2.92	0.31	0.18	1.97	3.89	20.66	0.26	0.11	14.39
O22D-4	3.45	1.27	0.67	2.19	3.21	15.21	0.21	0.16	179.90
O22D-5	7.23	1.59	0.62	1.96	2.53	16.35	0.36	0.16	145.77
O22D-6	4.46	2.64	0.6	2.09	2.45	14.58	0.35	0.12	14.41
O22D-7	2.48	1.61	0.14	2.14	1.43	9.51	0.12	0.07	10.90

Table 45. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site P25 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
P25D-1	3.97	1.32	7.31	0.09	0.28	27.36	2.05	432.68	562.2
P25D-2	0.44	0.4	2.44	0	0.06	27.95	0.4	90.78	229.82
P25D-3	0.14	0.1	14.29	0.01	0.11	14.41	0	26.69	1271.35
P25D-4	0.75	1.01	28.85	0.05	0.15	75.5	1.36	73.61	2540.46
P25D-5	0.49	0.93	9.47	0.08	0.11	101.33	2.29	106.65	869.43
P25D-6	0.91	1.23	5.73	0.12	0.31	139.32	3.33	151.53	488.12
P25D-7	0.88	1.46	4.4	0.09	0.2	165.17	4.16	170.04	325.9

Table 46. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site P25 bimonthly DDAW wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
P25D-1	13.41	5.99	3.97	2.20	0.56	4.04	1.43	1.72	34.94
P25D-2	3.66	0.64	0.44	2.11	0.36	1.62	0.77	0.47	37.69
P25D-3	13.15	0	0.14	1.71	0.63	13.2	0.14	0.13	29.77
P25D-4	21.55	0.55	0.75	2.15	1.3	25.45	1.26	0.71	97.08
P25D-5	9.63	0.59	0.49	1.69	0.37	7.95	1.15	0.92	30.72
P25D-6	8.62	1.5	0.91	1.96	0.37	3.81	1.89	1.26	13.14
P25D-7	4.47	0.83	0.88	2.11	0.42	2.75	1.99	1.45	15.74

Table 47. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J19 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
J19F-1	14.67	2.25	246.02	5.29	1.14	777.27	22.66	189.32	5991.59
J19F-2	11.83	0.34	78.66	7.03	2.06	697.33	5.14	66.41	6037.93
J19F-3	8.32	0.38	71.91	5.36	1.81	697.78	4.6	65.24	5924.94
J19F-4	8.26	0.32	44.91	3.63	1.54	530.47	4.32	45.72	5131.88
J19F-5	7.49	0.32	45.02	2.92	1.07	514.41	4.15	36.05	3833.02
J19F-6	9.17	0.23	47.41	3.12	0.98	557.77	4.61	30.6	2896.54
J19F-7	9.64	0.43	35.48	1.43	1.45	511.98	4.79	32.92	1696.54

Table 48. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site J19 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
J19F-1	178.64	13.2	14.67	6.50	52.65	52.99	15.32	1.06	571.59
J19F-2	789.89	3.84	11.83	3.33	6.62	65.28	0.99	0.42	688.40
J19F-3	679.91	3.22	8.32	2.85	5.38	54.94	0.97	0.35	557.72
J19F-4	495.64	3.13	8.26	2.66	3.43	36.93	0.57	0.31	519.88
J19F-5	394.19	1.24	7.49	2.27	1.49	32.28	0.58	0.22	308.83
J19F-6	341.93	5.69	9.17	2.30	1.24	25.42	0.36	0.19	317.56
J19F-7	176.61	2.43	9.64	2.47	0.91	15.53	0.65	0.18	158.23

Table 49. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J23 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
J23F-1	17.12	22.78	49.48	1.6	0.47	275.17	2.48	54.43	6181.09
J23F-2	4.52	0.72	75.83	7.85	0.17	29.07	0.17	17.44	4922.73
J23F-3	4.85	0.67	104.38	18.57	0.26	38.74	0.25	13.69	5418.63
J23F-4	7.30	0.71	146.64	33.34	0.48	69.18	2.02	32.68	6028.24
J23F-5	6.65	0.84	128.39	27.33	6.83	86.28	2.59	12.48	6486.32
J23F-6	10.17	1.35	186.74	39.02	0.62	170.51	3.64	16.23	6968.01
J23F-7	2.56	0.26	54.35	7.52	1.19	35.65	0.92	36.15	2560.85

Table 50. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site J23 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	**Mn**	**Ni**	**Pb**	**Se**	**Sc**	**Sr**	**Ti**	**V**	**Zn**
J23F-1	14.1	4.64	17.12	4.62	80.7	117.58	24.85	3.40	39.27
J23F-2	15.31	1.43	4.52	2.57	3.35	129.88	0.36	0.65	33.17
J23F-3	19.28	0.57	4.85	3.04	4.19	160.02	0.50	0.48	59.76
J23F-4	29.03	3.19	7.3	3.84	7.17	240.93	0.73	0.56	172.19
J23F-5	27.61	3.18	6.65	4.35	4.05	267.79	0.67	0.59	44.76
J23F-6	37.93	7.44	10.17	5.64	5.29	367.76	0.91	1.06	70.03
J23F-7	8.38	1.82	2.56	2.99	1.18	81.82	4.66	0.35	23.09

Table 51. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site K22 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
K22F-1	2.82	4.22	33.62	0.52	0.23	51.5	1.15	569.36	3406.41
K22F-2	0.39	2.17	264.57	0.92	0.61	39.66	0	78.95	5923.51
K22F-3	0.58	1.31	213.03	1.76	0.63	53.47	0.71	41.7	6003.7
K22F-4	0.36	0.23	97.85	1.4	0.24	33.06	1.02	45.41	4164.23
K22F-5	1.18	1.75	299.99	3.83	0.97	221.79	1.62	161.58	6629.98
K22F-6	0.90	1.1	150.79	1.65	0.36	221.98	1.39	121.9	7136.57
K22F-7	0.76	0.45	29.33	0.64	0.74	92.86	1.43	36.54	1849.2

Table 52. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site K22 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
K22F-1	72.2	4.38	2.82	2.61	18.47	42.68	2.57	2.90	13.79
K22F-2	550.63	1.82	0.39	3.03	10.33	268.86	1.25	0.66	166.08
K22F-3	425.98	2.06	0.58	2.43	7.38	201.1	0.91	0.73	215.68
K22F-4	202.63	7.89	0.36	2.06	3.05	91.22	0.11	0.28	197.03
K22F-5	794.52	2.06	1.18	3.13	6.97	371.56	0.65	0.52	441.03
K22F-6	415.35	2.3	0.9	2.29	3	192.18	0.15	0.41	256.50
K22F-7	83.41	3.2	0.76	2.41	0.95	41.23	0.27	0.36	52.83

Table 53. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in μg/L for site N23 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
N23F-1	1.85	37.46	117.57	0.51	1.05	62	23.25	457.38	6114.67
N23F-2	0	1.12	283.09	0.49	1.16	38.06	0.39	78.11	6176.84
N23F-3	0.35	2.05	427.52	1.39	1.8	83.78	5.83	115.51	6081.04
N23F-4	0.96	1.7	262.95	1.33	1.63	92.43	2.21	121.16	6050.48
N23F-5	1.56	4.14	470.33	1.14	1.67	243.27	4.64	334.59	6936.65
N23F-6	1.52	2.66	122.16	0.36	0.43	134.91	2.48	210.35	4899
N23F-7	0.40	0.79	25.02	0.14	0.61	67	1.71	89.76	1138.82

Table 54. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in μg/L for site N23 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	**Mn**	**Ni**	**Pb**	**Se**	**Sc**	**Sr**	**Ti**	**V**	**Zn**
N23F-1	482.05	8.72	1.85	3.96	89.79	68.76	11.25	0.98	130.89
N23F-2	1316.22	2.77	0	2.37	10.82	149.38	0.49	0.12	320.32
N23F-3	1815.64	2.67	0.35	2.70	13.5	203.76	1.01	0.16	657.37
N23F-4	1426.16	7.46	0.96	3.28	11.84	150.47	1.01	0.20	528.60
N23F-5	1969.41	4.14	1.56	2.53	8.07	236.7	0.81	0.34	695.49
N23F-6	522.34	2.23	1.52	2.07	2.18	60.2	0.44	0.26	190.59
N23F-7	91.86	2.09	0.4	2.30	0.69	13.75	0.37	0.14	58.96

Table 55. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site O22 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
O22F-1	0	2.15	307.68	0.06	0.34	24.25	0	660.32	1490.62
O22F-2	0	0.01	155.21	0.04	0.06	8.9	0	14.01	353.63
O22F-3	0	0	301.5	0.03	0.18	6.26	0	7.67	711.91
O22F-4	0	0	156.48	0.04	0.19	7.69	0.19	11.64	702.33
O22F-5	0.13	0	106.35	0.04	0.12	9.97	0.69	7.74	710.01
O22F-6	0.58	0.07	170.4	0.16	0.3	17.28	2.49	11.98	791.74
O22F-7	0.17	0.15	104.29	0.06	0.47	13.26	5.11	3.41	427.99

Table 56. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site O22 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
O22F-1	39.23	3.15	0	2.87	30.86	52.83	2.42	0.59	83.40
O22F-2	6.31	0.56	0	1.61	1.99	29.21	0.11	0.16	18.70
O22F-3	19.18	0.39	0	1.48	4.8	71.26	0	0.02	17.72
O22F-4	17.35	3.97	0	1.51	5.68	62.44	0.01	0.03	99.82
O22F-5	18.93	4.97	0.13	1.23	2.14	62.06	0	0.01	7.38
O22F-6	16.68	2.55	0.58	2.07	3.63	71.22	0.07	0.07	17.85
O22F-7	6.42	1.98	0.17	2.38	1.85	40.14	0.21	0.12	27.18

Table 57. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site P25 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
P25F-1	0.38	1.16	6.54	0.13	0.06	30.18	10.04	2361.36	615.48
P25F-2	0	0.23	3.45	0.07	0.15	17.31	0.36	38.95	299.32
P25F-3	0	0.12	12.12	0.06	0.04	19.03	0	38.4	948.99
P25F-4	3.60	0.36	24.07	0.09	0.08	63.22	1.86	85.41	2122.1
P25F-5	0.49	0.48	25.36	0.1	0.15	101.06	2.36	96.18	1470.48
P25F-6	0.88	0.83	9.31	0.08	0.07	135.44	3.58	128.66	860.92
P25F-7	0.54	0.27	11.05	0.1	0.28	87.13	1.76	75.63	990.48

Table 58. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site P25 bimonthly formaldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	**Mn**	**Ni**	**Pb**	**Se**	**Sc**	**Sr**	**Ti**	**V**	**Zn**
P25F-1	14.57	1.69	0.38	1.91	1.79	4.39	1.07	1.60	29.96
P25F-2	3.52	1.32	0	2.11	0.47	2.33	0.54	0.40	9.07
P25F-3	10.36	0.06	0	1.71	0.71	8.95	0.18	0.22	26.77
P25F-4	16.16	2.15	3.6	1.95	1.78	21.87	0.98	0.50	21.56
P25F-5	14.16	1.16	0.49	1.85	0.82	18.94	1.08	0.57	20.37
P25F-6	10.07	2.53	0.88	1.88	0.48	7.51	1.38	0.94	12.71
P25F-7	6.74	11.08	0.54	2.14	0.54	9.17	0.97	0.44	10.28

Table 59. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J19 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
J19G-1	10.74	0.78	165.95	2.09	0.39	436.5	17.25	2476.05	4082.5
J19G-2	5.68	0.27	88.87	1.5	0.26	342.62	5.7	55.97	3094.27
J19G-3	5.24	0.26	70.41	1.17	0.34	374.14	3.93	34.86	2307.44
J19G-4	9.07	0.22	49.79	0.91	0.3	630.07	6.78	57.51	2547.62
J19G-5	12.18	0.42	41.31	1.19	0.47	689	8.48	62.39	1983.94
J19G-6	9.80	0.36	38.25	1.22	0.35	537.77	6.98	47.83	1709.5
J19G-7	9.60	0.46	42.02	1.01	0.47	618.56	6.62	22.7	1651.41

Table 60. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site J19 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
J19G-1	81.14	3.62	10.74	2.38	4.84	24.45	8.18	0.45	289.61
J19G-2	152.77	0.76	5.68	1.51	1.11	22.59	0.77	0.26	213.47
J19G-3	145.33	0.02	5.24	1.21	0.84	16.68	0.53	0.19	157.87
J19G-4	175.82	1.62	9.07	0.88	0.62	17.95	0.46	0.18	330.79
J19G-5	138.21	2.22	12.18	2.25	1.06	14.74	0.78	0.31	178.82
J19G-6	119.03	3.36	9.8	2.35	0.92	12.16	0.68	0.25	131.42
J19G-7	118.04	1.53	9.6	2.38	0.82	12.08	0.50	0.23	140.87

Table 61. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J23 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
J23G-1	17.70	3.49	20.54	0.78	0.07	208.69	0.86	296.76	3496.32
J23G-2	8.71	1.11	23.37	1.79	0.14	39.86	0.86	12.97	3445.25
J23G-3	17.03	1.68	78.26	5.53	0.28	121.91	4.05	22.42	4347.15
J23G-4	8.78	0.9	38.99	3.42	0.18	95.39	2.6	14.15	4182.21
J23G-5	5.28	0.41	22.16	2.16	0.22	53.58	2.29	14.1	2436.74
J23G-6	4.03	0.52	23.2	2.1	0.12	94.6	2.3	16.01	2407.87
J23G-7	3.95	0.30	20.8	2.23	0.24	65.26	1.95	5.96	2133.58

Table 62. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site J23 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
J23G-1	4.27	2.82	17.7	1.60	4.84	52.33	6.68	4.61	14.07
J23G-2	2.49	3.83	8.71	1.65	1.11	64.46	0.51	2.25	14.79
J23G-3	8.23	1.67	17.03	2.08	0.84	181.58	1.33	2.74	167.76
J23G-4	4.03	1.21	8.78	1.78	0.62	88.62	0.75	1.94	108.19
J23G-5	2.01	2.27	5.28	2.38	1.06	52.85	0.90	1.42	5.95
J23G-6	2.44	1.56	4.03	2.95	0.92	52.54	0.68	1.40	10.69
J23G-7	2.83	1.89	3.95	2.71	0.82	48.84	0.76	1.12	14.78

Table 63. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site K22 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
K22G-1	3.31	2.2	21.76	0.12	0.01	37.74	0	1784.4	1482.3
K22G-2	0.57	0.37	35.23	0.18	0.12	17.33	0	46.89	2628.48
K22G-3	0.50	0.23	55.52	0.24	0.05	34.82	0	30.86	4047.46
K22G-4	1.77	1.49	118.82	0.75	0.37	164.29	2.54	107.09	4463.45
K22G-5	0.98	0.93	50.68	0.47	0.3	111.48	1.86	73.58	4506.03
K22G-6	0.99	0.95	45.66	0.56	0.22	123.68	1.94	98.32	3855.98
K22G-7	0.74	0.63	34.48	0.41	0.56	92.98	1.27	52.08	2726.16

Table 64. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site K22 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
K22G-1	30.7	0.61	3.31	1.05	3	21.54	5.54	4.45	7.99
K22G-2	35.2	20.41	0.57	1.14	0.82	42.59	0.31	0.54	45.06
K22G-3	79.02	0	0.5	0.74	0.86	67.63	0.07	0.33	29.35
K22G-4	210.34	9.03	1.77	1.38	2.23	161.52	0.97	1.17	158.77
K22G-5	113.02	1.63	0.98	2.13	1.88	77.2	0.90	0.93	56.73
K22G-6	101.85	1.54	0.99	2.33	1.52	65.86	0.61	0.92	57.64
K22G-7	81.22	2.3	0.74	2.31	1.07	49.05	0.58	0.82	44.13

Table 65. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in μg/L for site N23 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
N23G-1	2.35	3.79	14.75	0.18	0.03	22.16	0.44	425.18	867.4
N23G-2	0.28	0.93	80.26	0.12	0.12	51.34	0	258.27	4175.8
N23G-3	0.43	0.83	102	0.17	0.19	39.66	0	70.81	4307.98
N23G-4	0.86	2.03	146.58	0.19	0.25	123.53	1.66	249.75	4568.82
N23G-5	0.72	1.58	48.48	0.14	0.17	97.53	2.38	162.1	2793.53
N23G-6	1.06	1.36	30.71	0.39	0.27	104.36	3.48	176.68	1671.67
N23G-7	0.69	1.16	21.36	0.12	0.32	94.43	2.71	152.42	1126.17

Table 66. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in μg/L for site N23 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	**Mn**	**Ni**	**Pb**	**Se**	**Sc**	**Sr**	**Ti**	**V**	**Zn**
N23G-1	28.22	0.77	2.35	0.97	2.62	6.08	4.48	1.90	48.33
N23G-2	150.45	0.1	0.28	1.30	1.59	44.41	0.62	0.29	121.67
N23G-3	250.49	0.14	0.43	1.01	1.63	52.06	0.60	0.24	145.17
N23G-4	376.64	0.69	0.86	0.95	1.88	76.73	0.80	0.34	195.44
N23G-5	106.52	1.34	0.72	1.97	1.38	25.9	1.17	0.35	65.58
N23G-6	66.21	6.87	1.06	2.04	1.03	16.23	1.03	0.32	40.59
N23G-7	51.5	3.14	0.69	2.19	0.81	10.65	0.99	0.31	36.17

Table 67. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in μg/L for site O22 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
O22G-1	1.83	1.74	220.45	0.08	0.13	67.57	0	1128.07	1138.08
O22G-2	0.80	0.14	91.44	0.08	0.03	7	0.48	6.04	202.9
O22G-3	0.19	0.09	95.57	0.06	0.03	6.72	0	9.38	243.08
O22G-4	0.18	0.07	82.7	0.09	0.06	10.65	0.21	5.1	411.93
O22G-5	0.13	0.16	122.17	0.07	0.37	15.82	2.28	11.5	552.34
O22G-6	0.31	0.16	106.19	0.08	0.27	24.05	3.44	16	490.42
O22G-7	0.21	0.11	67.75	0.07	0.26	19.99	3.44	5.2	375.72

Table 68. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in μg/L for site O22 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
O22G-1	21.97	0.57	1.83	0.98	4.16	40.88	5.99	1.84	25.84
O22G-2	2.17	0.13	0.8	1.02	0.54	18.87	0.13	0.22	4.69
O22G-3	4.99	0	0.19	0.88	0.65	20.32	0.05	0.08	21.77
O22G-4	6.82	1.52	0.18	0.70	0.89	31.79	0	0.04	9.75
O22G-5	8.39	1.84	0.13	1.96	2.41	39.4	0.30	0.15	32.29
O22G-6	8.15	3	0.31	2.10	2.18	36.08	0.35	0.25	156.69
O22G-7	6.14	4.37	0.21	2.19	1.43	25.32	0.31	0.12	316.46

Table 69. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site P25 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
P25G-1	3.39	5.09	15.1	0.12	0.15	58.53	1.75	592.04	1176.6
P25G-2	0.98	1.26	12.87	0.12	0.09	26.85	0.25	59.64	1365.8
P25G-3	2.07	5.76	86.03	0.34	0.86	224.59	3.66	324.31	4327.11
P25G-4	1.15	1.7	14.89	0.12	0.18	108.78	4.01	157.69	1232.88
P25G-5	1.00	2.31	24.11	0.14	0.35	174.52	3.96	188.33	1939.81
P25G-6	1.29	2.18	15.76	0.11	0.2	158.31	3.98	159.62	1298.93
P25G-7	0.82	2.14	12.52	0.12	0.47	151.73	2.89	146.5	1015.64

Table 70. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site P25 bimonthly glutaraldehyde treatment wetting and drying experiment for sampling intervals 1-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
P25G-1	43.38	3.94	3.39	0.95	2.22	10.62	4.82	2.13	86.75
P25G-2	53.52	0.7	0.98	1.37	0.41	12.5	0.62	1.09	12.88
P25G-3	295.85	2.12	2.07	1.17	2.5	72.31	3.41	2.61	77.72
P25G-4	55.53	1.25	1.15	1.11	0.42	12.39	1.46	1.73	142.92
P25G-5	88.29	0.95	1	1.92	0.85	21.06	2.11	1.53	49.59
P25G-6	59.45	1.78	1.29	1.96	0.69	13.22	1.94	1.55	15.47
P25G-7	47.78	5.62	0.82	2.15	0.62	10.46	1.85	1.49	19.96

Table 71. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J19 bimonthly always wet experiment for sampling intervals 2-7.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
J19HB-2	14.81	1.51	1137	0.44	1.52	742.81	1.62	3434.84	5593.4
J19HB-3	14.05	1.79	1649.09	0.24	0.92	432.85	1.01	3626.24	4981.89
J19HB-4	9.70	1.31	1498.06	0.58	0.53	293.56	2.22	820.78	3745.92
J19HB-5	6.05	1.09	1597.44	0.32	0.38	297.15	2.9	1610.9	3324.43
J19HB-6	2.37	0.45	1469.3	0.45	0.15	214.69	4.71	293.7	2531.72
J19HB-7	1.91	0.38	1326.16	0.48	0.12	172.83	2.6	284.13	1869.48

Table 72. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site J19 bimonthly always wet experiment for sampling intervals 2-7.

Sample	**Mn**	**Ni**	**Pb**	**Se**	**Sc**	**Sr**	**Ti**	**V**	**Zn**
J19HB-2	436.41	8.08	14.81	3.61	9.3	79.55	6.32	1.46	59.41
J19HB-3	400.99	1.96	14.05	2.83	7.65	101.64	4.29	0.58	23.29
J19HB-4	290.58	3.36	9.7	2.56	6.92	89.18	3.73	0.27	80.33
J19HB-5	165.96	1.08	6.05	2.44	4.18	95.21	3.03	0.28	58.10
J19HB-6	43.12	5.14	2.37	2.36	3.15	78.74	2.09	0.14	94.21
J19HB-7	43.15	1.54	1.91	2.30	2.28	67.13	1.54	0.12	93.33

Table 73. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site J23 bimonthly always wet experiment for sampling intervals 2-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
J23HB-2	10.26	0.81	45.74	0.71	0.27	110.11	3.04	187.26	5743.24
J23HB-3	4.27	0.39	49.25	0.49	0.22	74.02	0	210.41	5700.55
J23HB-4	1.87	0.28	35.12	1.58	0.18	40.23	0.22	36.39	3709.61
J23HB-5	4.39	0.3	41.13	4.08	0.08	58.79	0.99	24.08	3129.81
J23HB-6	5.35	0.27	42.58	5.38	0.06	66.14	0.88	24.13	3083.17
J23HB-7	2.12	0.29	31.1	3.7	0.11	50.93	0.57	19.11	2125.81

Table 74. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site J23 bimonthly always wet experiment for sampling intervals 2-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
J23HB-2	12.38	2.11	10.26	3.57	9.28	110.51	3.93	2.47	13.21
J23HB-3	9.13	2.21	4.27	3.37	9.69	113.45	4.57	1.72	6.98
J23HB-4	3.99	2.48	1.87	2.96	7.34	77.55	3.39	0.93	11.12
J23HB-5	2.57	1.54	4.39	2.58	4.09	75.46	2.78	1.55	14.54
J23HB-6	2.52	1.14	5.35	2.53	4.1	75.73	2.59	1.47	13.81
J23HB-7	1.39	3.5	2.12	2.70	2.93	56.3	2.00	1.98	13.22

Table 75. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site K22 bimonthly always wet experiment for sampling intervals 2-7.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
K22HB-2	0.77	0.6	70.6	0.12	0.43	63.01	0	430.81	4987.14
K22HB-3	0	0.37	55.78	0.15	0.21	56.64	0	330.59	4055.77
K22HB-4	0.12	0.29	44.72	0.13	0.14	44.5	0.09	93.49	3115.52
K22HB-5	0.21	0.18	46.91	0.15	0.03	48.79	0.47	86.77	2964.03
K22HB-6	0.14	0.17	48.77	0.17	0.02	45.92	1.74	40.36	2916.19
K22HB-7	0.27	0.23	39.39	0.17	0.43	42.49	0.29	66.84	2144.65

Table 76. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site K22 bimonthly always wet experiment for sampling intervals 2-7.

Sample	**Mn**	**Ni**	**Pb**	**Se**	**Sc**	**Sr**	**Ti**	**V**	**Zn**
K22HB-2	74.58	3.05	0.77	4.17	6.18	86.81	2.63	0.98	112.17
K22HB-3	59.32	1.58	0	2.52	5.04	68.17	3.11	0.38	17.73
K22HB-4	24.25	2.25	0.12	2.38	4.23	54.09	1.83	0.42	15.23
K22HB-5	17.34	0.48	0.21	2.09	2.31	54.46	1.24	0.56	13.67
K22HB-6	9.35	0.79	0.14	2.04	2.12	54.32	0.81	0.57	38.81
K22HB-7	14.05	0.89	0.27	2.17	1.52	41.8	0.74	0.61	14.18

Table 77. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site N23 bimonthly always wet experiment for sampling intervals 2-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
N23HB-2	2.49	13.25	170.21	0.18	1.25	85.78	1.77	3806.53	6151.2
N23HB-3	0	1.9	131.47	0.06	0.59	42.74	0	3683.74	5932.24
N23HB-4	0	0.49	60.24	0.09	0.33	28.14	0.37	2848.49	4871.44
N23HB-5	1.19	0.56	61.13	0.08	0.23	43.79	1.57	2196.83	3968.57
N23HB-6	0.18	0.31	54.19	0.05	0.2	35.13	0.65	1454.73	3027.79
N23HB-7	0.37	0.56	43.07	0.07	0.15	44.42	0.67	1363.61	2243.86

Table 78. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site N23 bimonthly always wet experiment for sampling intervals 2-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
N23HB-2	622.03	13.51	2.49	3.18	17.45	94.83	9.27	0.99	22.84
N23HB-3	428	0.8	0	2.81	12.85	73.85	6.17	0.32	5.12
N23HB-4	286.09	2.04	0	2.38	7.57	36.75	4.05	0.14	25.63
N23HB-5	247.16	1.09	1.19	2.05	4.02	35.15	2.60	0.17	16.16
N23HB-6	163.58	1.64	0.18	2.14	3.15	29.05	1.67	0.09	14.40
N23HB-7	92.09	2.19	0.37	2.19	2.22	22.52	1.59	0.12	16.38

Table 79. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site O22 bimonthly always wet experiment for sampling intervals 2-7.

Sample	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mg
O22HB-2	0.33	0.45	655.12	0.05	0.53	21.91	0.17	115.34	984.46
O22HB-3	0	0.25	585.88	0.06	0.49	14.9	1.33	59.87	825.34
O22HB-4	0	0.23	468.73	0.05	0.39	10.29	7.9	23.12	591.88
O22HB-5	0.16	0.3	531.2	0.08	0.31	8.94	0.67	16.15	643.33
O22HB-6	0.12	0.28	478.34	0.06	0.25	8.49	0.72	14.27	561.89
O22HB-7	0.24	0.31	432.33	0.06	0.91	8.2	0.35	12.77	468.53

Table 80. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site O22 bimonthly always wet experiment for sampling intervals 2-7.

Sample	Mn	Ni	Pb	Se	Sc	Sr	Ti	V	Zn
O22HB-2	38.72	4.42	0.33	2.34	9.69	86.81	1.16	0.24	51.36
O22HB-3	18.13	1.72	0	1.62	10.87	68.17	1.06	0.18	27.19
O22HB-4	7.86	12.45	0	1.96	7.92	54.09	1.39	0.18	33.57
O22HB-5	6.61	1.33	0.16	1.97	5.33	54.46	0.84	0.23	8.14
O22HB-6	4.73	1.22	0.12	2.03	4.23	54.32	0.62	0.22	3.40
O22HB-7	2.06	1.51	0.24	2.22	3.46	41.8	0.66	0.25	43.44

Table 81. ICP-MS-HEX data of aqueous concentrations of aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), and magnesium (Mg) in µg/L for site P25 bimonthly always wet experiment for sampling intervals 2-7.

Sample	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mg**
P25HB-2	0.18	4.13	33.26	0.06	0.41	113.47	1.44	1575.67	3121.84
P25HB-3	0	0.67	25.75	0.02	0.19	84.94	0	880.13	1998.71
P25HB-4	0.53	0.19	18.11	0.07	0.13	47.13	0.18	351.11	1174.1
P25HB-5	0.22	0.24	13.77	0.06	0.02	58.51	0.44	238.19	993.03
P25HB-6	0.25	0.16	5.09	0.05	0	55.75	0.98	131.99	698.82
P25HB-7	0.14	0.23	5.82	0.05	0.14	67.32	0.55	109.35	756.15

Table 82. ICP-MS-HEX data of aqueous concentrations of manganese (Mn), nickel (Ni), lead (Pb), selenium (Se), scandium (Sc), strontium (Sr), titanium (Ti), Vanadium (V), and zinc (Zn) in µg/L for site P25 bimonthly always wet experiment for sampling intervals 2-7.

Sample	**Mn**	**Ni**	**Pb**	**Se**	**Sc**	**Sr**	**Ti**	**V**	**Zn**
P25HB-2	133.59	4.4	0.18	1.91	3.84	35.64	3.73	0.82	16.72
P25HB-3	83.49	0.71	0	1.63	2.9	21.14	2.23	0.21	5.64
P25HB-4	52.12	9.28	0.53	1.61	1.95	12.69	1.01	0.11	52.48
P25HB-5	43.69	0.44	0.22	1.61	0.95	10.26	1.08	0.20	47.16
P25HB-6	20.85	0.26	0.25	1.69	0.73	2.53	1.00	0.16	67.17
P25HB-7	16.81	1.76	0.14	1.91	0.69	3.67	0.55	0.27	54.66

APPENDIX IV

APPENDIX IV

ICP-HEX-MS Standard Preparation (after Icopini et al. 1998)

All standards are prepared in a 100mL volumetric flask with 500μg/L ultra pure nitric acid.

Solution A: 1mg/L Co, Ni, Cu, V, Cd, Pb, As, Ti, Hg, Sc (100μl of each element)

Solution B: 10mg/L Zn, Sr, Se, Al (1000μl of each element)

Solution C: 10mg/L Cr, Ba, Mn, Fe, K, Mg (1000μl of each element)

Solution D: 1mg/L In, Bi, Tb, Ge (100μl of each element)

Solution E: 20μg/L in 500ml flask at 4% nitric acid

Formula for Solution E:

$$\text{ml of } HNO_3 = \frac{(4\%\ HNO_3)(500\text{ml})}{70\%\ HNO_3 \text{ solution}}$$

Standard 1: 50μl Solution A, 250μl Solution B, 100μl Solution C

Standard 2: 100μl Solution A, 500μl Solution B, 1000μl Solution C

Standard 3: 500μl Solution A, 1000μl Solution B, 50μl Solution C

Standard 4: 1000μl Solution A, 2000μl Solution B, 100μl Solution C

Standard 5: 2000μl Solution A, 3000μl Solution B, 200μl Solution C

APPENDIX V

APPENDIX V

Detailed results for DDAW, formaldehyde, glutaraldehyde, always wet, and bimonthly treatments for the four elements (chromium, iron, maganese, and strontium)

1.0 Chromium

DDAW (Distilled Deionized Autoclaved Water) Treatment (Figure 6)

J19: At time zero, chromium concentrations were 209 ppb. The concentration of chromium released ranges between 200 and 400 ppb over the 90 days, with a trend of increasing concentration over time.

N23: Chromium concentration for time zero was 11 ppb. Chromium concentrations always increased. At 90 days, the chromium concentration was 161 ppb.

P25: The chromium concentration at time zero was 27 ppb. The concentration of chromium released from the sample decreased to 14 ppb at day 30. After day 30, the concentration increased for the remainder of the experiment where the final concentration was 165 ppb.

J23: Chromium concentration for time zero was 27 ppb. After a decrease to 9 ppb at day 15, the graph illustrates a general increasing trend to 116 ppb.

K22: The chromium concentration at time zero was 38 ppb. The chromium concentration decreased to 9 ppb on day 15. For the remainder of the experiment, the chromium concentration increased where the final concentration was 67 ppb.

O22: At time zero, chromium concentration was 21 ppb. Chromium concentration decreased to a low concentration of 3 ppb on day 30. Beyond 30 days, the chromium concentration increased to a final concentration of 17 ppb.

Always Wet Treatment (Figure 7)

For J19 always wet treatment, the amount of chromium released began 743 ppb and steadily decreased over the duration of the experiment to 173 ppb. In contrast, J19 DDAW treatment (Figure 6) began at a lower concentration (209 ppb) and the trend increased over time.

In the always wet treatment for N23 and P25, chromium concentrations began at 86 ppb and 113 ppb respectively. The chromium released decreased to a steady state at 45 days to a concentration of 43 ppb and 58 ppb respectively. However, in the DDAW treatment N23 and P25, chromium concentrations began at a lower concentration and increased over time.

The chromium concentration for J23, K22, and O22 always wet treatment decreased over time to a steady state concentration. The concentration range for J23 was 110 to 51 ppb. The concentrations of K22 ranged from 63 to 43 ppb. Finally the concentrations at O22 ranged from 22 to 8 ppb. However, the DDAW treatment J23 and K22 chromium concentrations increased over the duration of the experiment. For O22 the concentration (in the DDAW) at the end was approximately equal to the starting concentration. The pattern was a “v” shape rather than the steady increase noted by the other always wet treatments J23 and K22.

Formaldehyde Treatment (Figure 8)

J19: At time zero, chromium concentrations were at 777 ppb. Over time, there was a slight decrease in the concentration of chromium released with the final concentration of 551 ppb.

In contrast to the DDAW treatment (Figure 6), the sample treated with the formaldehyde treatment decreased over time whereas the sample with the DDAW treatment increased over time. The concentrations of chromium eluded were different between the two treatments. Higher concentrations of chromium were eluded in the sample treated with the formaldehyde concentration approximately double the concentration of chromium in the sample treated with DDAW.

N23: The concentration of chromium at time zero was 62 ppb. After 15 days of drying, the chromium released decreased to a concentration of 38 ppb. For the following 45 days, there was an increase in chromium eluded resulting in a peak concentration of 243 ppb at day 60. After this peak, chromium concentrations decreased to 67 ppb by day 90 the final concentration.

For the first 45 days, both the formaldehyde (Figure 8) and DDAW (Figure 6) treatment samples showed an increasing trend, however, the samples from the formaldehyde treatment exhibited higher chromium concentrations. At day 60, the trends for the two treatments diverge. Chromium concentrations for samples that underwent the DDAW treatment increased by 50%. However, chromium concentrations for samples that underwent the formaldehyde treatment, there was a peak at day 60 with a subsequent decline of 50%.

P25: The chromium concentration at time zero was 30 ppb. This remained relatively constant until after day 30 where there was an increase in concentration of chromium released. The chromium concentration peaks at day 75 at 135 ppb followed by a decrease in chromium to a concentration of 87 ppb.

Chromium concentrations eluded from the formaldehyde (Figure 8) and DDAW (Figure 6) treatment samples were similar at time zero. Both treatments show a slight decrease in chromium concentrations to day 30 followed by an increase. However, the soil that underwent the formaldehyde treatment had a peak in chromium concentration released at day 75; whereas, the soil that underwent the DDAW treatment continued to increase to day 90.

J23: The concentration of the fluid collected at time zero was 275 ppb. Chromium concentrations decreased rapidly to a concentration of 29 ppb at day 15. From day 15, there is a gradual increase in chromium concentrations eluded from the soil at site J23 with a peak concentration (170 ppb) of chromium on day 75. However, by day 90, the chromium released had returned to a lower concentration of 35 ppb.

Initial concentrations of the formaldehyde treatment (Figure 8) and the DDAW treatment (Figure 6) differed. The concentration of the DDAW treatment was lower than the concentration of the formaldehyde treatment at time zero. The formaldehyde treatment ranged in concentrations from 29 to 275 ppb. Concentration ranges for the DDAW treatment were from 10 to 70 ppb. Both treatments demonstrated an initial 15-day decrease in chromium concentrations. Following the initial decrease, the concentration increased in both treatments with a 17% increase in the DDAW treatment and a 7% increase in the formaldehyde treatment; however, the formaldehyde treatment shows a peak at day 75 followed by a decrease; whereas, the DDAW treatment exhibits a continual increase.

K22: Chromium concentrations at time zero were 51 ppb. This amount released remained relatively constant until day 45 where the chromium concentrations peaked at 221 ppb and remained at that level until day 60. After day 60, there was a decrease to 129 ppb to day 90.

In comparison to the DDAW treatment, both the DDAW (Figure 6) and formaldehyde (Figure 8) treatments released similar concentrations in the early stages of the experiment. Concentrations in the DDAW treatment increased over time but did not result in chromium concentration as high as those seen in the formaldehyde treatment. Furthermore, there was no peak in chromium concentrations in the DDAW treatment; whereas, there was a peak present between days 60 and 75 in the formaldehyde treatment.

O22: At time zero, the chromium concentration was 24 ppb. After 30 days, there was a decline in the chromium eluded to a low of 6 ppb. Following day 30, chromium concentrations released increased until day 75 where it peaked at 17 ppb. After this chromium peak, the concentration decreased to 13 ppb at day 90.

Glutaraldehyde Treatment (Figure 9)

J19: The concentration of chromium released at time zero was 436 ppb. Initially, there was a decrease in chromium concentration to a low of 342 ppb at day 15. Following the low at day 15, there was an increase in chromium concentrations to day 60 where the concentration was 689 ppb. After the peak at day 60, the chromium concentrations decreased to 573 ppb and then increased to a final concentration of 618 ppb at day 90.

Chromium concentrations at time zero differ between the formaldehyde (Figure 8) and glutaraldehyde (Figure 9) treatments, where the glutaraldehyde samples exhibited lower concentrations. An overall increase can be seen in the glutaraldehyde treatment where as the formaldehyde treatment was closer to steady state over time.

In comparison to the DDAW treatment (Figure 6), the glutaraldehyde treatment sample (Figure 9) had a higher concentration at time zero. Both the glutaraldehyde and DDAW treatment samples had an increase in concentration over the duration of the experiment.

N23: The concentration at time zero was 22 ppb. There is an increase to 15 days where the chromium concentration was 51 ppb. A decrease of 12 ppb occurs between 15 and 30 days. After 30 days, there is an increase to a peak at 45 days where the concentration was 124 ppb. The concentration then decreases to a steady state starting at 60 days and continuing the duration of the experiment.

N23 graph from the DDAW treatment (Figure 6) exhibits a constant increase over the duration of the experiment. However, the graph from the glutaraldehyde treatment (Figure 9) shows a series of increases and decreases over the duration of the experiment. Furthermore, the initial concentrations of N23 for the DDAW treatment and the glutaraldehyde treatment differ significantly.

P25: At time zero, the concentration of chromium was 59 ppb. The trend decreased to 27 ppb on day 15. Then, there was an increase to a peak at 30 days at a concentration of 225 ppb. Finally, it reached a steady state of 158 ppb after 60 days.

The formaldehyde treatment trend (Figure 8) increases after day 30 to a peak at day 75; however, the glutaraldehyde treatment graph (Figure 9) peaks at day 30 and then decreases before reaching a steady state.

The DDAW graph for P25 (Figure 6) illustrates an increase for the duration of the experiment starting at 30 days. Once again, the glutaraldehyde graph (Figure 9) reaches a steady state after 60 days.

J23: At time zero the chromium concentration was 209 ppb. After the first drying interval, the concentration of chromium reached a low of 40 ppb. There, the concentration of chromium increased to a peak of 121 ppb at day.

In comparison to the formaldehyde treatment (Figure 8), the glutaraldehyde treatment sample (Figure 9) had a lower chromium concentrations. The trends vary between the two treatments with the formaldehyde having a longer period of increase to a peak at 75 days followed by a decrease to day 90. However, the glutaraldehyde treatment graph (Figure 9) shows a curve with two peaks and three lows following the initial high at time zero.

The chromium concentrations for time zero were higher in the glutaraldehyde treatment samples (Figure 9) than in the DDAW treatment samples (Figure 6). The DDAW treatment samples increased over the duration of the experiment; whereas, the glutaraldehyde treatment samples exhibited a drastic decrease at the beginning, followed by smaller increases and decreases in the concentration.

K22: The chromium concentrations at time zero was 38 ppb. The concentration of chromium decreases to a low at day 15 and then increases to a peak of 164 ppb at day 45. Following the peak, the concentration decreased 50 ppb to day 60 followed by an increase of 12 ppb the next sampling interval. Between the second peak at day 75 and day 90 there was a final decrease of 31 ppb.

Both the formaldehyde (Figure 8) and glutaraldehyde (Figure 9) treatments increase the concentrations eluded after day 45 in the formaldehyde treatment and day 30 in the glutaraldehyde treatment.

The DDAW treatment graph (Figure 6) shows an increase from time 30 to time 90 days. In comparison, the glutaraldehyde treatment graph (Figure 9) showed chromium concentrations increasing after day 30 to a peak and then decreasing.

O22: The concentration of chromium at time zero was 68 ppb. At day 15, a sharp decline in the concentration occurred. After the decline, a small increase of 18 ppb occurred between day 30 and day 75.

Both the formaldehyde (Figure 8) and glutaraldehyde (Figure 9) treatment graphs have a sharp decline between day 0 and day 15. Both the formaldehyde (Figure 8) and glutaraldehyde (Figure 9) treatment graphs illustrate an increase in chromium concentrations after day 30 and with the highest concentration being at day 75.

In comparison, the DDAW (Figure 6) and glutaraldehyde (Figure 9) treatments exhibited similar curves with a sharp decline at the start, the lowest concentration at 30 days, and the peak concentration at 75 days.

Bimonthly Drying Treatment (Figure 10)

The plots represent a six-month monitoring of chromium released from the cyclic wetting and drying of soils. The sample for J19 bimonthly drying treatment was 60 ppb at time zero (Figure 10) and peaked at a concentration of 403 ppb at approximately 30 days. After the peak, the chromium concentration declines to a steady state of approximately 40 ppb. Chromium released from soils representing cyclic wetting and drying in the field (N23 and P25) had an initial concentration of 3 ppb and 7 ppb respectively. The chromium released in the soils increased and then decreased over time. The peaks occurred at approximately the same time for both soils. However, the percent increase and decrease was greater in P25 then N23. Chromium released from soils representing continuously wet field conditions with high organic matter, J23 and K22, had initial concentrations of 4 ppb and 8 ppb respectively (Figure 10). They behaved similarly by increasing to peak concentrations of 36 ppb and 58 ppb respectively after the first drying interval and then decreasing to a steady state. However, K22 bimonthly drying treatment increases at the end of the experiment where J23 bimonthly drying treatment remained at steady state. Chromium concentrations eluded from the site with continuously wet field conditions and low organic matter (O22) decreased from 14 ppb at time zero to a steady state with chromium concentrations fluctuating between 5 and 8 ppb.

2.0 Iron

DDAW Treatment (Figure 11)

J19: At time zero, the concentration of iron was 103 ppb. The concentration of iron decreased to a minimum concentration at day 45 of 33 ppb. The concentration increased 13 ppb over the remaining 45 days of the experiment.

N23: Iron concentration for time zero was 262 ppb. The graph illustrates a decrease of 200 ppb to the minimum concentration at day 30. After day 30, the concentration increases to 185 ppb on day 90.

P25: The initial concentration of iron was 433 ppb. The graph illustrates a drastic decrease in concentration to 27 ppb on day 30. After day 30 the concentration increases to 170 ppb on day 90.

J23: Iron concentration for time zero was 78 ppb. The concentration decreased to approximately 10 ppb and reached a steady-state for the remainder of the experiment.

K22: At time zero, the concentration of iron was 657 ppb. The graph illustrates a decrease to a concentration of 30 ppb at day 15. There was an increase to 86 ppb at day 30. After day 30, the concentration of iron remained at steady-state for the remainder of the experiment.

O22: Iron concentration for time zero was 50 ppb. There was a decrease in concentration to day 45. There was an increase to 71 ppb at day 60, and then the concentration decreased for the remainder of the experiment.

Always Wet Treatment (Figure 12)

J19: The concentration of iron was above 3000 ppb for 30 days. After 30 days, the concentration started to decrease to 820 ppb on day 45. The concentration increased from day 45 to day 60 to a concentration of 1610 ppb. After day 60, the concentration of iron decreased to a steady-state of 285 ppb.

N23: Initial concentration of iron was 3806 ppb. The concentration of iron decreased over the duration of the experiment to 1363 ppb. Between days 75 and 90, the concentration started to achieve a steady-state 1400 ppb.

P25: The concentration of iron at the start of the experiment was 1576 ppb. The concentration decreased to day 75 where the concentration reached a steady-state. The final concentration of iron was 109 ppb.

J23: The initial concentration was 187 ppb. The concentration increased at day 30 to 210 ppb. After day 30, the concentration decreased and reached a steady-state of approximately 19 ppb at day 45.

K22: Initial concentration of iron was 431 ppb. The concentration of iron decreased until day 45 where a steady-state was reached at approximately 67 ppb.

O22: The initial concentration of iron was 115 ppb. The graph illustrates a decrease to day 45. After day 45, a steady-state was reached. The final concentration of iron was 12 ppb.

Formaldehyde Treatment (Figure 13)

J19: At time zero, the iron concentration was 189 ppb. The concentration of iron decreased for the remainder of the experiment.

In comparison to the DDAW treatment (Figure 11), the concentration of iron at time zero was higher in the formaldehyde treatment. The trends differed after 45 days where the formaldehyde treatment continued to decrease and the DDAW treatment slightly increased.

N23: The initial concentration of iron at time zero was 457 ppb. The concentration decreased to 78 ppb at time 15 days. The concentration of iron then increased to 335 ppb at time 60 days. Finally, the concentration decreased for the remainder of the experiment with a final concentration of 90 ppb.

The concentration of iron at time zero was higher for the formaldehyde treatment (Figure 13) than the DDAW treatment (Figure 11). The trends of the two treatments are different. The graph of the DDAW treatment (Figure 11) shows a decrease followed by an increase. On the other hand, the graph of the formaldehyde treatment shows an additional decrease after the increase at 60 days.

P25: At time zero, the concentration of iron was 2361 ppb. There was a significant decrease in iron concentration to 38 ppb on day 30. After day 30, the concentration of iron increased to 128 ppb on day 75. The concentration decreased between day 75 and day 90 with a final concentration of 75 ppb. The trends of both the DDAW treatment (Figure 11) and the formaldehyde treatment (Figure 13) were similar.

J23: The initial concentration of iron was 54 ppb. The concentration decreased to 14 ppb on day 30. There was an increase in iron concentration to 162 ppb on day 45. The graph illustrates a decrease to day 60 followed by an increase to 36 ppb at day 90.

In comparison to the graph of the DDAW treatment (Figure 11), the graph of the formaldehyde treatment had a series of decreases and increases where the DDAW treatment graph showed a decrease to a steady-state.

K22: At time zero, the concentration of iron was 569 ppb. The graph illustrates a decrease in iron to 41 ppb on day 30. The concentration of iron increased from day

30 to a concentration of 162 ppb on day 60. Finally, the graph shows a decrease for the remainder of the experiment.

The DDAW treatment graph (Figure 11) is similar to the formaldehyde treatment graph except for the increase and subsequent decrease surrounding day 60 in the formaldehyde treatment.

O22: The time zero concentration was 660 ppb. The concentration decreased between time zero and 15 days. At 15 days the concentration reached a steady-state of approximately 10 ppb for the remaining 75 days.

A high concentration of iron at day 60 of the DDAW treatment and the initial concentration of iron in the formaldehyde treatment were the only two differences between the graphs. The initial concentration of the formaldehyde treatment (Figure 13) was 10 times higher than the initial concentration of iron in the DDAW treatment.

Glutaraldehyde Treatment (Figure 14)

J19: The concentration of iron at time zero was 2476 ppb. After time zero, there was a decrease to day 15 where the graph remained at steady-state for the remaining 75 days with a final concentration of 50 ppb.

The trends are similar to the graph of the DDAW treatment (Figure 11) and the formaldehyde treatment (Figure 13). The initial concentration was much higher in the glutaraldehyde treatment, but after time zero, the graph illustrates a steady-state similar to the formaldehyde treatment with similar concentrations.

N23: At time zero, the concentration of iron was 425 ppb. The concentration of iron decreased from time zero to day 30 where the concentration was 70 ppb. After day 30, the concentration of iron increased to 250 ppb on day 45. After day 60, the concentration of iron reached a steady-state of approximately 160 ppb.

In comparison to the graph of the formaldehyde treatment (Figure 13), the graph of the glutaraldehyde treatment (Figure 14) had similar concentrations of iron. The trends, however, were different. Both exhibited an initial decrease after time zero. A second high point was reached a different times according for each treatment. For the formaldehyde treatment (Figure 13), the second peak was reached at 60 days. The second peak was reached at 45 days in the graph of the glutaraldehyde treatment (Figure 14). In the glutaraldehyde treatment, the graph (Figure 14) shows the iron concentration reaching a steady-state after the second peak. On the other hand, in the formaldehyde treatment, the graph (Figure 13) shows the iron concentration continuing to decrease after the second peak.

The graph of the DDAW treatment (Figure 11) has a decrease to day 30 followed by an increase for the remainder of the experiment. This is different than the steady-state shown in the graph of the glutaraldehyde treatment (Figure 14).

P25: The initial concentration was 592 ppb. The concentration of iron decreased to 60 ppb on day 15. After day 15, the concentration of iron increased to a second high point at day 30 of 325 ppb. After the second high point, the graph shows the concentration of iron reaching a steady-state of approximately 160 ppb.

In comparison to the graph of the formaldehyde treatment (Figure 13) and the graph of the DDAW treatment (Figure 11), the graph of the glutaraldehyde treatment is different. The graphs of the glutaraldehyde treatment had a peak concentration at day 30.

J23: At time zero, the concentration of iron was 297 ppb. After time zero, the concentration decreased to a steady-state of approximately 14 ppb.

The graph of the glutaraldehyde treatment (Figure 14) is similar to the graph of the DDAW treatment (Figure 11). The graph of the formaldehyde treatment (Figure 13) does not reach a steady-state like the graphs of the DDAW treatment (Figure 11) and the glutaraldehyde treatment (Figure 14).

K22: The initial concentration of iron was 2039 ppb. There was a decrease to 30 days where the concentration was 31 ppb. The concentration of iron increased to 107 ppb at 45 days. The concentration decreased to 73 ppb on day 60. The concentration increased again to day 75. Finally, the concentration decreased to 52 ppb on day 90.

In comparison to graphs for the DDAW treatment (Figure 11) and the formaldehyde treatment (Figure 13), the initial concentration of iron was higher in the glutaraldehyde treatment (Figure 14). The three graphs have different trends. However, a general trend of a sharp decrease followed by increases and decreases can be found in all three graphs.

O22: At time zero, the concentration of iron was 1128 ppb. After time zero, the concentration of iron decreased and then reached steady-state of approximately 10 ppb.

The graphs of the glutaraldehyde treatment (Figure 14) and the formaldehyde treatment (Figure 13) are similar. They both differ from the DDAW treatment by the peak at day 60 in the DDAW treatment graph (Figure 11). Initial concentrations of iron are also different where the glutaraldehyde treatment sample is double the formaldehyde treatment sample, which is ten times higher than the DDAW treatment.

Bimonthly Drying Treatment (Figure 15)

J19: This site is always dry in the field. For the first 30 days the concentration of total iron decreased. On day 45, the peak on the trend is reached. The concentrations decline after the peak with a few smaller increases for the duration of the experiment.

N23: After a short decline for the first 30 days, the concentrations increase to a peak at 60 days. After the peak, the concentrations decrease for the duration of the experiment.

P25: The concentration starts high and then the concentrations decrease to day 30. Between days 30 and 60 the concentrations increase to a second smaller peak. After the second peak, the concentrations decrease for the remainder of the experiment.

J23: The graph starts with small increases and decreases followed by a peak of 97 ppb at day 60. After day 60 there is a sharp decline to day 75 followed by a small increase for 30 days. The graph then decreases for 15 days followed by a small increase for the remainder of the experiment.

K22: The graph increases from time zero to 127 ppb on day 45. After day 45, the graph decreases followed by a series of small-scale increases and decreases for the remainder of the experiment.

O22: The graph peaks after 15 days of drying and is followed by a sharp decline. The remainder of the graph consists of small scale increases and decreases.

3.0 Manganese

DDAW Treatment (Figure 16)

J19: Initially, the concentration of manganese was 11 ppb. The concentration increased to a concentration of 41 ppb on day 60. The concentration then slightly decreased for the remaining 30 days.

N23: The initial concentration of manganese was 8 ppb. The concentration of manganese increased for the entire 90 days of the experiment to 27 ppb.

P25: At time zero, the concentration of manganese was 13 ppb. The concentration decreased to 4 ppb on day 15. The concentration increased to 22 ppb on day 45. The concentration then decreased for the remaining 45 days to 5 ppb.

J23: The initial concentration of manganese was 0.44 ppb. The concentration increased to day 45 where the concentration was 1.44 ppb. From day 45 to day 90 the concentration decreased to 0.8 ppb.

K22: At time zero, the concentration of manganese was 8 ppb. The concentration of manganese increased to 36 ppb on day 45. The concentration then decreased to day 60. After day 60, the concentration increased to 53 ppb on day 75 and then decreased to 38 ppb on day 90.

O22: The manganese concentration at time zero was 5 ppb. The concentration decreased to 1 ppb on day 15. After day 15, the concentration increased to 7 ppb on day 60. The concentration then decreased for the remaining 30 days.

Always Wet Treatment (Figure 17)

J19: The initial concentration of magnesium was 436 ppb. The concentration decreased to a steady-state of approximately 43 ppb on day 75.

N23: Initially, the concentration of manganese was 622 ppb. The concentration decreased 530 ppb for the 90 days of the experiment.

P25: The initial manganese concentration was 134 ppb. The concentration of chromium decreased to a final concentration of 18 ppb on day 90.

J23: Initially, the manganese concentration was 12 ppb. The concentration decreased 11% for the duration of the experiment.

K22: The initial manganese concentration was 75 ppb. The concentration decreased to 9 ppb on day 75. After day 75, the concentration of manganese increased to 14 ppb on day 90.

O22: The initial concentration of manganese was 39 ppb. The concentration of manganese decreased for the remainder of the 90 days where the final concentration was 2 ppb.

Formaldehyde Treatment (Figure 18)

J19: Initially, the concentration of manganese was 179 ppb. The concentration increased to the highest concentration of 790 ppb on day 15. After day 15, the concentration decreased for the remaining 75 days with a final concentration of 177 ppb.

In comparison to the DDAW treatment graph (Figure 16), the graph of formaldehyde treatment (Figure 18) illustrated the opposite trend. The DDAW treatment concentrations increased to day 60 and then decreased, where the graph of formaldehyde treatment increased to day 15 and then decreased for the remaining 75 days. The formaldehyde treatment samples had higher concentrations than the DDAW treatment samples for the entire experiment.

N23: The initial concentration of manganese was 482 ppb. The concentration increased 19% to day 60 with a small decrease at day 45. After day 60, the concentration decreased to remaining 30 days to a final concentration of 92 ppb.

Manganese concentrations for the formaldehyde treatment samples were higher than the DDAW treatment samples. The DDAW treatment concentrations (Figure 16) increased for the entire experiment. On the other hand, the concentrations of the formaldehyde treatment (Figure 18) increased to day 60 and then decreased for the remaining 30 days.

P25: At time zero, the concentration of manganese was 15 ppb. The concentration decreased to day 15 with a concentration of 4 ppb. After day 15, the concentration increased to 16 ppb on day 45. The concentration then decreased for the remaining 45 days.

In comparison, the DDAW treatment graphs (Figure 16) and formaldehyde treatment graphs (Figure 18) display similar in trends. The concentrations both decrease for the first 15 days, increase for the next 30 days, and decrease for the remaining 45 days.

J23: The manganese concentration at time zero was 14 ppb. The concentration increased to 38 ppb on day 75. After day 75, the concentration of manganese decreased to 8 ppb on day 90.

The concentrations of manganese in the formaldehyde treatment samples (Figure 18) were higher than the concentration of manganese in the DDAW treatment samples (Figure 16). In comparison, the two graphs exhibited different trends. The DDAW treatment concentrations (Figure 16) had a peak at day 45 followed by a general steady-state trend for the entire experiment. On the other hand, the formaldehyde treatment graph (Figure 18) increased to day 75 and then decreased to day 90.

K22: Initially, the concentration of manganese was 72 ppb. The concentration increased to 550 ppb on day 15. After day 15, the concentration decreased to 203 ppb at day 45. The concentration increased again to 795 ppb on day 60. Manganese concentrations decreased for the remaining 30 days.

In comparison, the concentrations of manganese were higher in the formaldehyde treatment samples (Figure 18) than in the DDAW treatment samples (Figure 16). The DDAW treatment concentrations showed an increased for the 90 days. Conversely, the concentrations of the formaldehyde treatment showed an initial increased followed by a series of increases and decreases.

O22: At time zero, the concentration was 39 ppb. The concentration decreased to 6 ppb on day 15, and then the concentration increased to day 30. After day 30, the concentration reached a steady-state of approximately 17 ppb until day 60. After day 60, the concentration decreased for remaining 30 days.

Concentrations of manganese are higher in formaldehyde treatment samples (Figure 18) than in the DDAW treatment (Figure 16). The trends of both graphs are similar. The graphs are at steady-state for the majority of the experiment. The concentration ranges for the formaldehyde treatment is between 6 and 19 ppb for all concentrations except for the initial concentration, and the range of manganese concentration for DDAW treatment was between 1 and 7 ppb.

Glutaraldehyde Treatment (Figure 19)

J19: Initially, the concentration of manganese was 81 ppb. The concentration increased to 175 ppb to day 45 with a small decrease at day 30. The concentration of manganese than decreased to a steady-state of approximately 119 ppb on day 75.

In comparison to the DDAW treatment and the formaldehyde treatment graphs, the concentration of manganese in the glutaraldehyde treatment samples are intermediate. All three of the graphs have trends that increase and then decrease over time.

N23: At time zero, the concentration of manganese was 28 ppb. The concentration increased to 377 ppb at 45 days. The concentration decreased for the remaining 45 days to a final concentration of 52 ppb.

The concentrations of glutaraldehyde treatment samples (Figure 19) are intermediate between those of the formaldehyde treatment samples (Figure 18) and DDAW treatment samples (Figure 16). The formaldehyde and glutaraldehyde treatment concentrations (Figure 18 and 19 respectively) increase followed by a decrease. On the other hand, the DDAW treatment graph (Figure 16) increased for the entire 90 days.

P25: The initial concentration of manganese was 43 ppb. The concentration increased to 296 ppb on day 30. The concentration decreased to a steady-state at day 45.

The highest concentration of manganese was in the glutaraldehyde treatment samples (Figure 19). The general trend of all the treatments is a high concentration at day 30 or day 45 followed by a decrease or steady-state.

J23: At time zero, the concentration of manganese was 4 ppb. The concentration decreased to 2 ppb on day 15. After day 15, the concentration increased to the highest concentration of 8 ppb on day 30. The concentration decreased to day 60 where the concentration reached a steady-state of approximately 3 ppb.

The concentrations of the glutaraldehyde treatment samples (Figure 19) are intermediate between the formaldehyde treatment (Figure 18) and the DDAW treatment (Figure 16) samples. The trends of the glutaraldehyde treatment graph (Figure 19) are similar to the trends of the DDAW treatment graph (Figure 17).

K22: The initial concentration of manganese was 31 ppb. The concentration increased to day 45 where the concentration was 210 ppb. The concentration decreased for the remaining 45 days to a final concentration of 81 ppb.

The trends of the glutaraldehyde treatment graph (Figure 19) were different than the formaldehyde treatment graph (Figure 18) and the DDAW treatment graph (Figure 16). It differs from the formaldehyde treatment graph (Figure 18) by the lack of two peaks of that graph, instead a single peak at day 45 was observed (Figure 19). The DDAW treatment graph (Figure 16) differs because the concentrations increase for all 90 days.

O22: Initially, the concentration of manganese was 22 ppb. The concentration decreased to 2 ppb on day 15. The concentration then increased to a steady-state where the concentrations ranged between 5 and 8 ppb.

In comparison, the glutaraldehyde treatment and formaldehyde treatment were similar in concentration and trends. However, the DDAW treatment concentrations had a peak at day 90 and the concentrations were higher than the glutaraldehyde treatment.

<u>Bimonthly Drying Treatment (Figure 20)</u>

J19: The initial concentration of manganese was 12 ppb. The highest concentration of manganese was 127 ppb on day 15. After day 15, the concentration of manganese decreased with small increases at days 45 and 75.

N23: The initial concentration of manganese was 6 ppb. The concentration of manganese increased from day 15 to a peak of 14 ppb on day 60. From day 60 to day 75 the concentration decreased followed by an increase to the highest peak of 17 ppb. After the second peak, the concentration decreased for the remainder of the experiment.

P25: The initial concentration of manganese was 5 ppb. After an initial decrease from time zero to day 15, the concentration increases to 13 ppb on day 90. After day

90, the concentration of manganese decreases for the remainder of the experiment to a concentration of 3 ppb.

J23: The concentrations of manganese vary between 0 and 2 ppb for the entire experiment. There were two peaks of approximately 2 ppb on day 45 and 75.

K22: The initial concentration of manganese was 4 ppb. The concentration of manganese increases to a peak of 15 ppb on day 60. After day 60, the concentration of manganese decreases for the remainder of the experiment.

O22: The initial concentration of manganese was 2.37 ppb. The concentration increases to 3 ppb and is followed by a decrease. There is one smaller peak before the decrease to the final concentration, which was less than 1 ppb.

4.0 Strontium

DDAW Treatment (Figure 21)

J19: The initial concentration of strontium was 8 ppb. The concentration increased to 15 ppb on day 60. The concentration decreased from day 60 to day 75 followed by an increase over the last 15 days to a final concentration of 12 ppb.

N23: At time zero, the concentration of strontium was 2 ppb. The concentration increased to 24 ppb on day 45. After day 45, the concentration decreased to a steady-state of approximately 14 ppb.

P25: Initially, the strontium concentration was 4 ppb. From time zero to day 15, the concentration decreased to 1 ppb. After day 15, the concentration increased to 25 ppb on day 45. The concentration decreased for the remaining 45 day to a final concentration of 3 ppb.

J23: The initial strontium concentration was 10 ppb. The concentration increased to 144 ppb on day 30. After day 30, the concentration decreased to a steady-state of approximately 23 ppb.

K22: Initially, the strontium concentration was 12 ppb. From time zero to day 45, the concentration increased to 148 ppb. After day 45, the concentration decreased for the remaining 45 days to 35 ppb.

O22: At time zero, the strontium concentration was 24 ppb. The concentration of strontium decreased for the entire 90 days with a small increase at day 30 to a final concentration of 9 ppb.

<u>Always Wet Treatment (Figure 22)</u>

J19: The initial concentration of strontium was 80 ppb. The concentration increased to 101 ppb on day 30, and decreased to 89 ppb on day 45. After day 45, the concentration of strontium increased to 95 ppb on day 60. After day 60, the concentration decreased for the remaining 30 days to a final concentration of 67 ppb.

N23: Initially, the concentration of strontium was 95 ppb. The concentration of strontium decreased for the entire duration of the experiment to 22 ppb.

P25: The initial strontium concentration was 36 ppb. The strontium concentration decreased for the remaining 75 days to 3 ppb.

J23: The initial concentration of strontium was 110 ppb. The concentration stayed at a steady-state to day 30. After day 30, the concentration of strontium reached a second steady-state to day 75 of approximately 76 ppb. After day 75, the concentration decreased to 56 ppb on day 90.

K22: Initially, the concentration of strontium was 86 ppb. The concentration decreased to 54 ppb on day 45. At day 45 the concentration was at a steady-state of approximately 54 ppb for 30 days. After day 75, the concentration decreased to 41 ppb.

O22: Initially, the strontium concentration was 112 ppb. The concentration decreased to 78 ppb on day 45. The concentration increased to 92 ppb on day 60. Following the increase, the concentration decreased for the remaining 30 days to a final concentration of 72 ppb.

Formaldehyde Treatment (Figure 23)

J19: The initial strontium concentration was 53 ppb. The concentration increased from time zero to 65 ppb on day 15. After day 15, the concentration decreased for the remaining 75 days to a final concentration of 16 ppb.

The formaldehyde treatment (Figure 23) concentrations decreased for most of the experiment. This is different from the general increasing trend of the DDAW treatment (Figure 21).

N23: Initially, the strontium concentration was 69 ppb. The concentration increased to 204 ppb on day 30. The concentration decreased at day 45; however, the concentration increased again to 237 ppb on day 60. After day 60, the concentration decreased for the remaining 30 days to 14 ppb.

In comparison to the DDAW treatment graph (Figure 21), both graphs had an increase followed by a decrease. The peak before the decrease was 15 days later in the formaldehyde treatment graph (Figure 23).

P25: At time zero, the strontium concentration was 4 ppb. The concentration initially decreased to 2 ppb on day 15. After day 15, the concentration increased to day 45 where the concentration was 22 ppb. The concentration then decreased to 8 ppb on day 75. There was a final increase after day 75 to day 90.

Except for the final increase, the DDAW treatment graph (Figure 21) and the formaldehyde treatment graph (Figure 23) were similar in trends and concentrations.

J23: Initially, the strontium concentration was 118 ppb. The concentration of strontium increased to a peak at day 75 where the concentration was 368 ppb. After day 75, the concentration decreased to 82 ppb on day 90.

The concentration of strontium in the formaldehyde treatment graph (Figure 23) was higher than the concentration of strontium in the DDAW treatment graph (Figure 21). The peak concentration was 45 days later in the formaldehyde treatment graph (Figure 23) in comparison to the DDAW treatment graph (Figure 21).

K22: At time zero, the strontium concentration was 43 ppb. The concentration of strontium increased to 269 ppb on day 15. After day 15, the concentration decreased to 91 ppb on day 45. The strontium concentration increased to day 75 to a maximum of 371 ppb and, finally, the concentration decreased to 41 ppb on day 90.

In comparing the DDAW treatment graph (Figure 21) and the formaldehyde treatment graph (Figure 23), the concentrations are higher in the formaldehyde treatment graph (Figure 23). Another difference is the two peaks present in the formaldehyde treatment graph (Figure 23) versus the single peak present in the DDAW treatment graph (Figure 21).

O22: The initial concentration of strontium was 53 ppb. The strontium concentration decreased from time zero to 29 ppb on day 15. After day 15, the concentration increased to a steady-state of approximately 62 ppb for 45 days. After day 75, the strontium concentration decreased to 40 ppb on day 90.

In comparison, the concentration of the formaldehyde treatment graph (Figure 23) was higher than the concentration of the DDAW treatment graph (Figure 21). In contrast, the DDAW treatment graph (Figure 21) decreased for the duration of the experiment while the formaldehyde treatment graph (Figure 23) was at a steady-state for the majority of the experiment.

Glutaraldehyde Treatment (Figure 24)

J19: At time zero, the strontium concentration was 24 ppb. The concentration of strontium decreased for all 90 days to a final concentration of 12 ppb.

In comparison to the DDAW treatment graph (Figure 21), the concentrations are similar while the trends are opposite. The DDAW treatment graph (Figure 21) increases over the duration of the experiment, which is in contrast to the decreasing trend of the glutaraldehyde treatment (Figure 24). Both the formaldehyde treatment graph (Figure 23) and the glutaraldehyde treatment graph (Figure 24) have the decreasing for the 90 days.

N23: Initially, the strontium concentration was 6 ppb. The concentration increased to 77 ppb on day 45. After day 45, the concentration decreased for the remaining 45 days to 10 ppb.

The glutaraldehyde treatment graph (Figure 24) has a similar trend to the DDAW treatment graph (Figure 21). Both the aforementioned graphs have the peak present at 45 days. On the other hand, the formaldehyde treatment graph (Figure 23) has two peaks. The concentration is highest in the formaldehyde treatment graph (Figure 23) followed in decreasing concentration by the glutaraldehyde treatment graph (Figure 24) and the DDAW treatment graph (Figure 21).

P25: The initial strontium concentration was 11 ppb. The concentration increased to 72 ppb on day 30. After day 30, the concentration decreased to a steady-state of approximately 14 ppb for the remainder of the experiment.

In comparison to the DDAW treatment graph (Figure 21) and the formaldehyde treatment graph (Figure 23), the glutaraldehyde treatment graph (Figure 24) has a similar trend of a single peak leading to a steady-state. However, the peak occurred 15 days earlier in the glutaraldehyde treatment graph (Figure 24) than the DDAW treatment.

J23: Initially, the strontium concentration was 52 ppb. The concentration of strontium increased to 182 ppb on day 30. After day 30, the concentration of strontium decreased to a steady-state of approximately 51 ppb.

The glutaraldehyde treatment graph (Figure 24) has similar trends to the DDAW treatment graph (Figure 21). In contrast, the glutaraldehyde treatment graph (Figure 24) peaked earlier than the formaldehyde treatment graph (Figure 23), and the glutaraldehyde treatment graph (Figure 24) has a lower concentration of strontium than the formaldehyde treatment graph (Figure 23).

K22: At time zero, the strontium concentration was 22 ppb. The concentration increased from time zero to 45 days where the concentration was 162 ppb. After day 45, the concentration decreased for the remaining 45 days to a concentration of 49 ppb.

Comparing the DDAW treatment graph (Figure 21) to the glutaraldehyde treatment graph (Figure 24), the trends and concentrations of the two graphs were similar. In contrast, the formaldehyde treatment graph (Figure 23) had two peaks to the one peak of the glutaraldehyde treatment graph (Figure 24).

O22: The initial concentration of strontium was 41 ppb. The concentration decreased to day 15. After day 15, the concentration increased to 39 ppb on day 60. After day 60, the concentration of strontium decreased for the remaining 30 days to a final concentration of 25 ppb.

The trends and concentration of glutaraldehyde treatment (Figure 24) were similar to the trends of the formaldehyde treatment (Figure 23). However, the trends are not the same as the DDAW treatment graph (Figure 21) where the concentration decreased over the entire experiment in the DDAW treatment graph and the concentration increased for 45 days before the decrease in the glutaraldehyde treatment graph (Figure 24).

Bimonthly Drying Treatment (Figure 25)

J19: The initial concentration of strontium was 4.16 ppb. From time zero to day 15 the concentration of strontium eluded increased to 27 ppb. After day 15, the concentration of strontium decreased in a step fashion and the concentration of strontium eventually went to zero.

N23: The initial concentration of strontium was 1.2 ppb. The concentration of strontium in solution increased from time zero to a concentration of 16 ppb on day 75. The concentration of strontium then decreased to day 135 where the concentration of strontium eluded was zero ppb.

P25: The initial concentration of strontium was 1.26 ppb. The concentration of strontium in solution increased to 16 ppb on day 90. After day 90, the concentration of strontium in solution decreased to zero ppb on day135.

J23: The initial concentration of strontium was 6.62 ppb. From time zero to day 15 the concentration of strontium in solution increased to 47 ppb. From day 15 to day 45 the concentration of strontium eluded decreased to 16 ppb. The concentration of strontium increased again from day 45 to day 75 to a concentration of 33 ppb. There was a decrease in strontium concentration to 13 ppb on day 105. After day 105, the concentration of strontium eluded increased to 22 ppb on day 120. After day 120, the concentration of strontium in solution was zero ppb.

K22: The initial concentration of strontium was 5.27 ppb. From time zero to day 15, the concentration of strontium in solution increased to 55 ppb. From day 15 to day 45, the concentration of strontium in solution decreased to 31 ppb. The concentration of strontium in solution increased to 61 ppb on day 60. From day 60 to day 135, the concentration of strontium decreased to 38 ppb. The final concentration of strontium was zero ppb.

O22: The initial concentration of strontium was 11 ppb. The concentration of strontium eluded increased to 20 ppb on day 15. From day 15 to day 45, the concentration of strontium decreased to 8 ppb. From day 45 to day 60, there was an increase in strontium concentration to 14 ppb. After day 60, the concentration of strontium in solution decreased. After day 135, the concentration of strontium in solution was zero ppb.

APPENDIX VI

APPENDIX VI

Dissolved Organic Carbon Results

Icopini and Long (1999) demonstrated that dissolved organic carbon (DOC) is important in controlling chromium concentrations in water. In the present experiment, the DOC relation to chromium was studied in samples that were not treated with microbialcidal fluids. In this experiment, there is not a correlation between DOC and chromium for the majority of the sites. Only one site (J19) shows a significant correlation between DOC and chromium; the R^2 values for J19 weekly (Figure 26) and bimonthly (Figure 27) are 0.7648 and 0.8736 respectively. The R^2 values for the other sites range from 0.0004 to 0.6732.

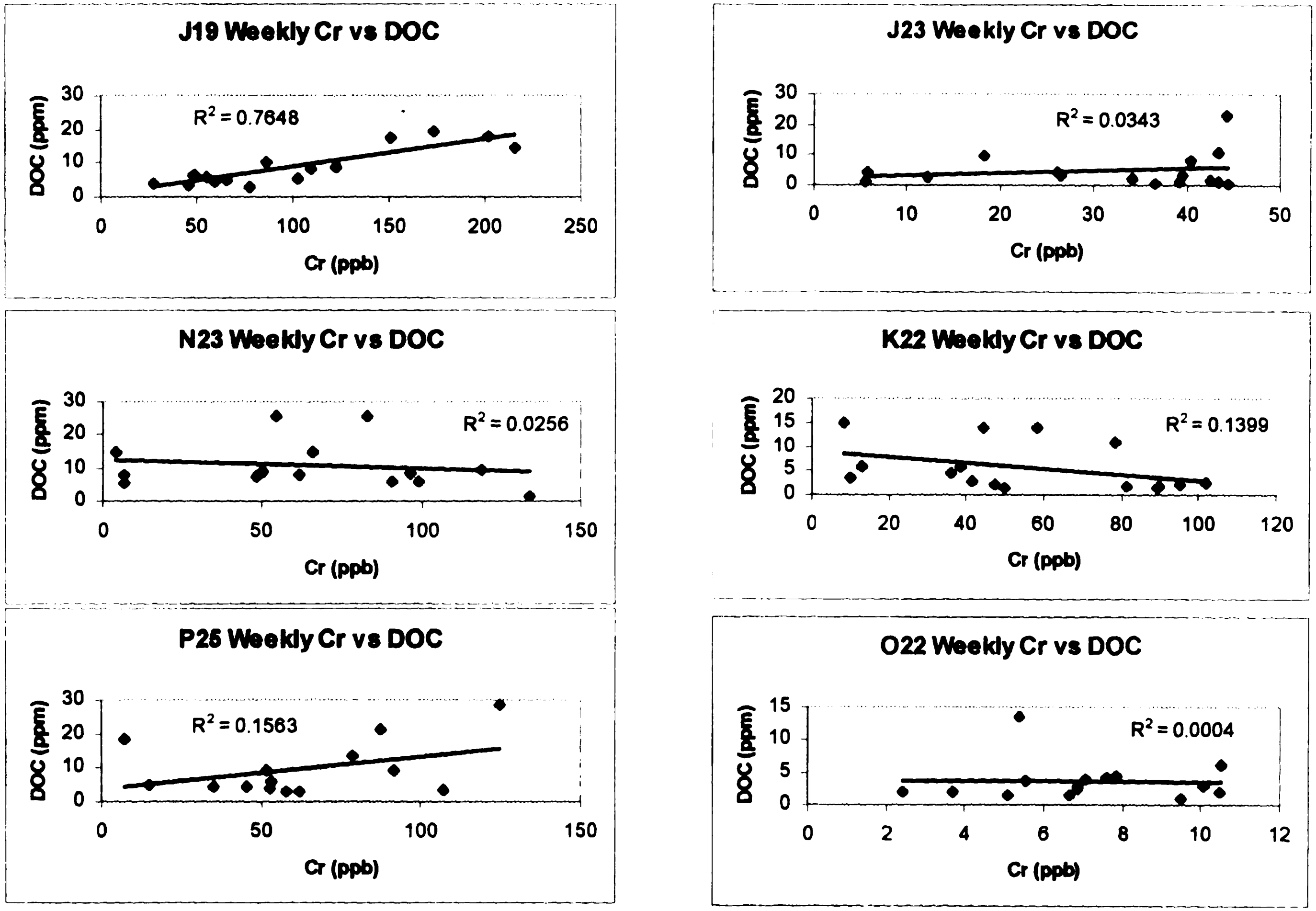


Figure 26: Graph of chromium concentrations vs dissolved organic matter concentrations for the weekly sampling interval

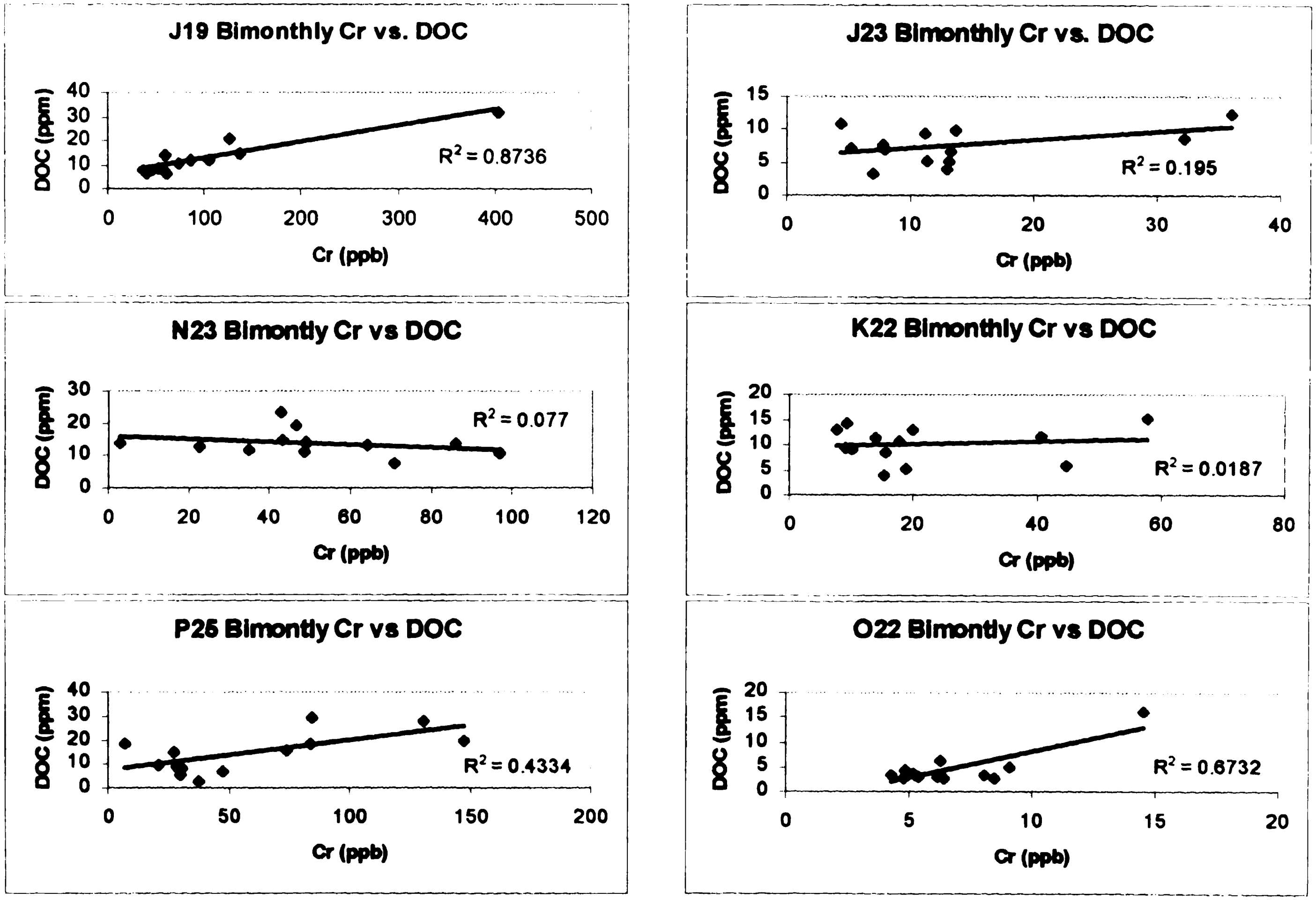


Figure 27: Graph of chromium concentrations vs dissolved organic matter concentrations for the bimonthly sampling interval

APPENDIX VII

APPENDIX VII

Concentrated Nitric Acid Leaching

Concentrated nitric acid leaching was performed on the soils used in the wetting and drying experiments. The values for the concentrations of chromium in the soil are presented in Table 6. From the results, it is clear that the amount of chromium in the soil does not influence the amount of chromium eluded during wetting and drying experiments. The values from the concentrated nitric acid leaching are similar to the summation of sequential extractions (Table 1) presented by Icopini et al. (1997, 1998, 1999) and Ellis (1999). The sites can be divided into three high concentration sites (J19, J23, and K22) and three lower concentration sites (N23, O22, and P25). The amount of chromium in solution does not correspond to the same concentration breaks. Concentrations from the wetting and drying experiments presented in Table 83 were placed in decreasing order of chromium concentration in solution: J19, N23, P25, K22, J23, and O22. Grouping sites according to the field saturation state was the best indicator of the relative concentration of chromium in solution.

Table 83: Concentration of chromium from concentrated nitric acid leaching including the order from highest concentration (1) to lowest concentration (6) of chromium in soil and in the solution from the distilled deionized autoclaved water treatment.

Sites	Cr (mg/kg) from the concentrated nitric acid leaching	Order of concentration from highest (1) to lowest (6) in the soil from the concentrated nitric acid leaching	Order of concentration from highest (1) to lowest (6) in distilled deionized autoclaved water treatment	Field Saturation State
J19	44,271	3	1	Always Dry
N23	10,716	4	2	Cyclic Wet and Dry
P25	14,522	5	3	Cyclic Wet and Dry
K22	47,203	2	4	Always Wet
J23	63,816	1	5	Always Wet
O22	1,915	6	6	Always Wet

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