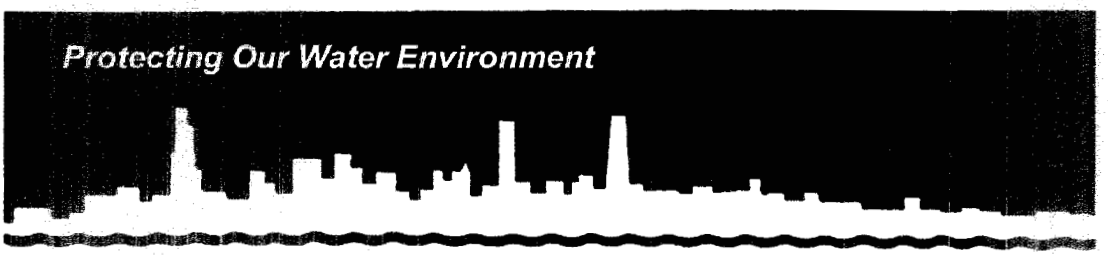

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

REPORT NO. 04-13

RECLAMATION OF THE ST. DAVID, ILLINOIS, COAL REFUSE PILE WITH BIOSOLIDS AND OTHER AMENDMENTS: EFFECTS ON CHEMICAL COMPOSITION OF COAL REFUSE, FORAGE AND SURFACE RUNOFF WATER

August 2004

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RECLAMATION OF THE ST. DAVID, ILLINOIS, COAL REFUSE PILE WITH BIOSOLIDS AND OTHER AMENDMENTS: EFFECTS ON CHEMICAL COMPOSITION OF COAL REFUSE, FORAGE AND SURFACE RUNOFF WATER

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August 2004

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

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ACKNOWLEDGMENTS

The authors acknowledge the field and laboratory staff at the Biosolids Utilization and Soil Science Section's Fulton County and Stickney locations for their various contributions to the project. Special thanks are also extended to Mrs. Sabina Yarn and Ms. Laura Franklin for formatting the report.

DISCLAIMER

Mention of proprietary equipment and chemicals in this report does not constitute endorsement by the Metropolitan Water Reclamation District of Greater Chicago.

SUMMARY AND CONCLUSIONS

The Metropolitan Water Reclamation District of Greater Chicago's (District) Fulton County, Illinois, land reclamation site includes approximately 140 ha of coal refuse, which produced acid mine drainage. About 32 ha of this coal refuse is located at St. David, Illinois, and is the focus of this study. In 1987, the District began a ten-year study, based on previous research, to determine the rates of biosolids, agricultural lime, and clay that can be used to reclaim the coal refuse. Single replicates of ten treatments were established on approximately 0.405-ha plots on the west lobe and side slopes of the coal refuse pile.

Six treatments consisted of an unamended control and amended plots receiving biosolids applications of 784, 1,568, 2,240, 2,800, and 3,360 Mg/ha. Two treatments consisted of amended plots receiving 784 and 1,568 Mg/ha biosolids plus 179 Mg/ha of lime. The final two treatments received the above two application rates of biosolids and lime, but had a 10.2-cm layer of clay placed between the biosolids and the coal refuse. The plots were seeded with alfalfa (*Medicago sativa* L.), alsike clover (*Trifolium hybridum*), bromegrass (*Bromus*

inermis), and tall fescue (*Festuca arundinacea* L.), along with a cover crop of cereal ryegrass (*Lolium multiflorum*).

Soil, vegetation, and surface runoff water samples were collected during the study. Soil samples were collected annually in 15-cm increments from the surface of the amended layer to a maximum depth of 60 cm in the coal refuse. The forage was sampled in 1988 and 1989 for yield determination and annually for chemical analysis. Surface water runoff was collected quarterly.

All the biosolids and lime treatments were effective in decreasing the acidity of the coal refuse and the surface water, and improving conditions for plant growth in the coal refuse. There was no noteworthy effect of the clay treatment on most of the coal refuse characteristics monitored or on plant growth and elemental concentrations. The effectiveness of the biosolids was attributed mostly to their ability to increase the buffering capacity of the coal refuse and to neutralize acid-forming ions. The treatments increased the pH and decreased the acidity, EC, and water-extractable Al and Fe in the coal refuse.

Compared to the unamended control where the pH was very low (pH 2.0 to 2.5) and acidity was high (5 to 25 $cmol_c/kg$), all the treatments effectively increased the pH (up to pH 7.1)

and reduced the acidity (to below to 5 $cmol_c/kg$) at all depths in the coal refuse. The effectiveness decreased with depth in the coal refuse, but did not appear to decrease with time during the study. The 2,240, 2,800, and 3,360 Mg/ha biosolids application rates were nearly as effective as the treatments in which lower biosolids rates (784 and 1,568 Mg/ha) were applied together with lime and with and without clay.

The concentrations of major plant nutrients and extractable metals in the coal refuse tended to increase with biosolids application rate and decreased with depth. There was no consistent effect of lime on the concentrations of these constituents. The exchangeable sodium percentage (ESP) tended to increase with biosolids rate to a maximum value of 2.5 and did not approach sodic levels (> 15).

Compared to the unamended control, which had no cover throughout the study, the forage yields in all the amendments were satisfactory. There were no consistent effects of biosolids rate or lime application on forage yield or on the concentration of metals in the forage tissue because all the biosolids application rates were at the plateau range of the plant growth response curve.

The forage tissue metal concentrations were generally highest at the beginning of the study, and then declined

sharply with time afterwards. This indicates that the bioavailability of metals applied through the biosolids amendments tended to decrease with time, most likely as a result of the reduction in soil acidity. Throughout the study, the computed forage metal uptake coefficients (UC) were much lower than the UC values for forage predicted for Pathway 6 of the USEPA Part 503 Risk Assessment model.

The treatments were effective in controlling the pH and acidity of the surface water runoff. Except for the 784 Mg/ha biosolids treatment, in which the pH of the surface water runoff was lower, the pH of the surface water runoff from all the other treatments ranged from approximately 5.9 to 6.8 and the acidity was usually lower than 5 $cmol_c/kg$.

The concentrations of NH_3-N, NO_3-N, and total P in the surface water runoff decreased with time, and by the end of the study they were relatively low. This increase in the concentration of nutrients represents only a short-term contribution to the degradation in surface runoff water quality. In the long run, the impact of the treatments on the concentration of nutrients is not significant as compared to the reduction in surface runoff water volumes, metal concentrations, and water acidity.

Overall, the results of the study showed that all the amendments were effective in providing adequate conditions for maintaining a vegetative cover on the coal refuse, and they significantly improved the quality of surface runoff water. When the coal refuse was amended with biosolids alone at rates greater than 1,568 Mg/ha, it provided similar or greater liming power than treatments using lower biosolids application rates applied together with 179 Mg/ha of lime. The biosolids amendments ameliorated the coal refuse to provided a favorable plant root environment throughout the ten-year period. This occurred by improving the physical properties, increasing the pH, decreasing the acidity, and increasing the levels of available essential plant nutrients (especially N and P) in the coal refuse.

The results of the study also confirmed the speculation by Pietz et al. (1989) that biosolids rates greater than 542 Mg/ha might be required to provide long-term reclamation of the St. David coal refuse. The 1,568 Mg/ha biosolids plus 179 Mg/ha of lime treatment is the recommended amendment for reclamation of other site coal refuse under similar conditions and project goals because it provides the best combination of effective reclamation while minimizing the potential for excessive application of nutrients and metals.

INTRODUCTION

Coal refuse consists of waste coal, rock pyrites, slate, shale, mill tailings, clay, or other non-marketable material separated from coal during the cleaning operation. In the eastern United States, coal refuse is usually acidic because of the oxidation of indigenous pyritic minerals, which produces sulfuric acid and soluble salt products (Nordstrom, 1982). Off-site movement of these compounds through runoff and leaching can adversely affect streams, rivers, and lakes. Haynes and Klimstra (1975) reported that there was about 1,712 ha of coal refuse material in Illinois, of which approximately 454 ha of this material was located in Fulton County as of June 30, 1971. Approximately 140 ha of this coal refuse material is located at the Fulton County land reclamation site that is owned and operated by the District.

Municipal biosolids have been used as an amendment to reclaim acid mine spoils (Hinkle, 1982; Stucky et al., 1980; Sopper and Seaker, 1984). However, few attempts have been made to reclaim coal refuse materials with biosolids. Previous research by Pietz et al. (1987 and 1989a, b, c) showed that municipal biosolids can be effective in establishing a vegetative cover and in improving the chemical composition and

percolate quality of acidic coal refuse material. The results of this research, conducted from 1974 to 1981, indicated that 900 to 1,350 dry Mg/ha of biosolids and 134 to 187 Mg/ha of lime were sufficient for effective long-term reclamation (>5 years) of coal refuse material.

For reclamation of acidic coal refuse material, it is important that the alkalinity be maintained above the threshold level to retard pyrite oxidation (Burt and Caruccio, 1986). Previous research (Pietz et al., 1987; Pietz et al., 1989a, b, c) showed that combinations of biosolids and lime were more effective than applications of these amendments individually for controlling the pH and reducing the concentrations of acid-forming cations Al and Fe. Consequently, for long-term reclamation, biosolids should be applied with lime to maintain the alkalinity required to neutralize the acidic products of pyrite oxidation in the coal refuse material. Clay can be beneficial because it provides a greater rooting depth for planted vegetation, reduces percolation into coal refuse material, and helps to stabilize the side slopes of coal refuse piles.

In 1987, the District initiated an experiment on a coal refuse pile located at St. David, Illinois, to determine the rates of biosolids, agricultural lime, and clay necessary for

long-term reclamation of coal refuse material. The experiment was initiated with the approval of the Illinois Environmental Protection Agency (IEPA). In this report, we present the results of the effects of these amendments on the chemical composition, revegetation, and surface water quality of the coal refuse material.

MATERIALS AND METHODS

Establishment of Plots

The experiment was started in 1987 on the west lobe and side slopes of a coal refuse pile located at St. David, Illinois. The experiment consisted of ten treatments (Table 1) each established on approximately 0.4 ha plots. A description of the plot layout is shown in Figure 1.

The treatments were established in four phases of operation. In the first phase, the site was graded to fill the existing erosion gullies on the surface and to remove the old, nonfunctioning terraces from the side slopes of the coal refuse pile. When this was completed, lysimeters (described later) were installed in each treatment.

In the second phase of operations, agricultural limestone was applied to the respective plots followed by anaerobically digested municipal biosolids from the District's Stickney Water Reclamation Plant (WRP) according to the rates described in Table 1. The biosolids were applied in 10.2-cm layers using a scraper. The amendments were incorporated with a chisel plow. The composition of the applied biosolids is shown in Table 2.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 1

AMENDMENTS APPLIED TO THE EXPERIMENTAL PLOTS AT THE ST. DAVID COAL REFUSE PILE

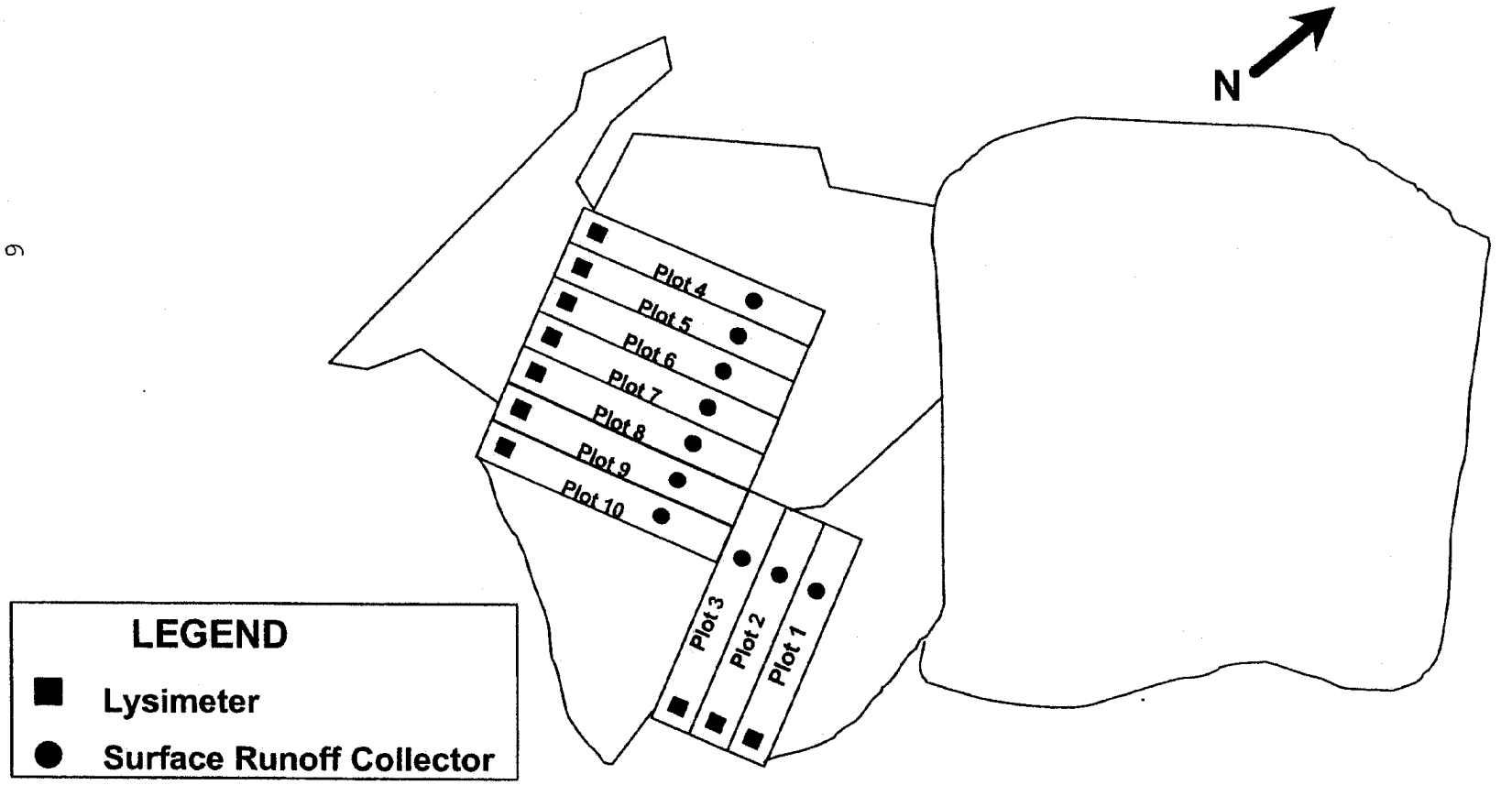
Plot Number	Treatment Composition[1]		
	Biosolids (Mg/ha)	Lime (Mg/ha)	Clay (cm)
1	0	0	0
2	784	0	0
3	784	179	0
4	784	179	10.2
5	1,568	0	0
6	1,568	179	0
7	1,568	179	10.2
8	2,240	0	0
9	2,800	0	0
10	3,360	0	0

[1]Application rates for biosolids and lime are on a dry weight basis.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 1

SCHEMATIC OF THE TEN EXPERIMENTAL PLOTS ON THE ST. DAVID COAL REFUSE PILE



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 2

CHEMICAL ANALYSIS OF THE BIOSOLIDS USED TO AMEND THE EXPERIMENTAL PLOTS AT THE ST. DAVID COAL REFUSE PILE

Chemical Constituent	Concentration
pH	6.9
----------Percent DW----------	
Total Solids	66.6
Total Volatile Solids	25.9
----------mg/kg DW----------	
Total P	8,320
Kjeldahl-N	7,830
NH_3-N	723
Zn	1,450
Cd	76
Cu	627
Cr	942
Fe	20,850
Ni	157
Pb	351
K	1,080
Na	427
Ca	36,680
Mg	16,930
Mn	480
Al	7,790
Hg	1

After the last layer of biosolids was applied, 10.2 cm of clay was applied to two of the plots (Table 1), and then the amendments were incorporated using a chisel plow.

In the third phase of operation, the amended surface of the plots was disked transverse to the slopes and then the plots were seeded. The planted vegetative cover consisted of broadcast seeding of cereal rye at a rate of 121 kg/ha, followed by broadcast seeding of alfalfa and alsike clover at a rate of 22.4 kg/ha. Next bromegrass and tall fescue were drill seeded at a rate of 11.2 kg/ha.

In the final phase, the plots were mulched. Those areas on each treatment which were flatter and had an average slope of ten percent or less were mulched with straw or old hay at the rate of 136 bales/ha. Portions of each treatment with slopes greater than ten percent were covered with a biodegradable paper fabric held in place with 10.2-cm staples.

Environmental Sampling

In the fall of every year the amended coal refuse material was sampled. Composite samples of 18 to 20 cores per treatment plot were collected in 15-cm increments from the surface through the treatment layers to the unamended coal refuse material. The maximum sampling depths were 60 cm for the

2,800 and 3,360 Mg/ha biosolids treatments, 45 cm for the 1,568 Mg/ha biosolids + lime + clay and the 2,240 Mg/ha biosolids treatments, and 30 cm for all the other treatments and the unamended coal refuse plot.

Forage yields were measured in 1988 and 1989 only. For forage tissue sampling, each treatment was divided into 16 subplots; four subplots on the upper and lower slopes of each treatment and eight plots on the longer middle slope. Plant samples were collected by harvesting a 1-m^2 area from each of the four subplots on the upper and lower slopes of each treatment. Plant samples in the middle slope portion of each treatment were collected from four of the eight subplots by random selection. The plant samples used for chemical analysis were obtained by making a composite sample of equal portions collected from the four subplots sampled on the upper, middle, and lower slope of each treatment.

Surface runoff was collected quarterly each year from each treatment as specified in a site permit issued by the IEPA. Surface runoff was collected by installing a collection device in the middle portion of the lower slope in each treatment. The collection device consisted of a 15.2-cm x 30.5-cm plastic container placed into a 25.4-cm x 45.7-cm plastic pipe underlain with pea gravel. Side wings to divert runoff to the

collection container consisted of 2.54 cm x 15 cm x 2.4 m treated lumber installed at a 45-degree angle to the collection container. A wooden platform was built to cover the top of the collection device so that rainfall would not enter the collection container.

Chemical Analyses

The chemical composition of the applied municipal biosolids was determined according to Standard Methods (1985). Coal refuse samples were air-dried and ground to pass a 2-mm stainless steel screen. The samples were analyzed for pH (McLean, 1982) and EC (Rhoades, 1982) using a 1:1 soil-water ratio. Exchangeable NH_4-N and NO_3+NO_2-N were determined in the 2M KCl extract according to Keeney and Nelson (1982). Total Kjeldahl nitrogen (TKN) was determined by the semi-micro Kjeldahl method (Bremner and Mulvaney, 1982). Available P was determined by the Bray P1 method and total P was determined in the HNO_3-$HClO_4$ acid digest. Total acidity, consisting of sequentially extracted water-soluble and 2 M KCl-extractable acidity, was determined according to Pietz et al. (1989a). Concentrations of Al, Ca, Fe, K, Mg, and Na were determined in the water extract. Concentrations of Al, Ca, Fe, Mg, and Na

were determined in the KCl extract. The concentrations of all metals were determined by atomic absorption spectroscopy.

Representative plant tissue samples collected from each treatment were dried at 65°C for 48 hours and ground in a Wiley mill to pass a 0.85-mm stainless steel screen. Samples were wet-ashed in a mixture of concentrated HNO_3 and $HClO_4$ acids and analyzed for metals as described by Pietz et al. (1989b).

Surface runoff samples collected quarterly were analyzed according to Standard Methods (1985) for pH, EC, total P, SO_4, NH_3-N, NO_3+NO_2-N, Al, Cd, Fe, Mn, Ni, Zn, and BOD_5.

RESULTS

Chemical Composition of Coal Refuse

The chemical composition of the treatments was monitored down to the depth of the unamended coal refuse. As previously indicated, this was to a depth of 60 cm for the 2,800 and 3,360 Mg/ha biosolids treatment, 45 cm for the 1,568 Mg/ha biosolids + lime + clay and the 2,240 Mg/ha biosolids treatments, and 30 cm for all other treatments and the unamended coal refuse plot.

COAL REFUSE pH AND ACIDITY

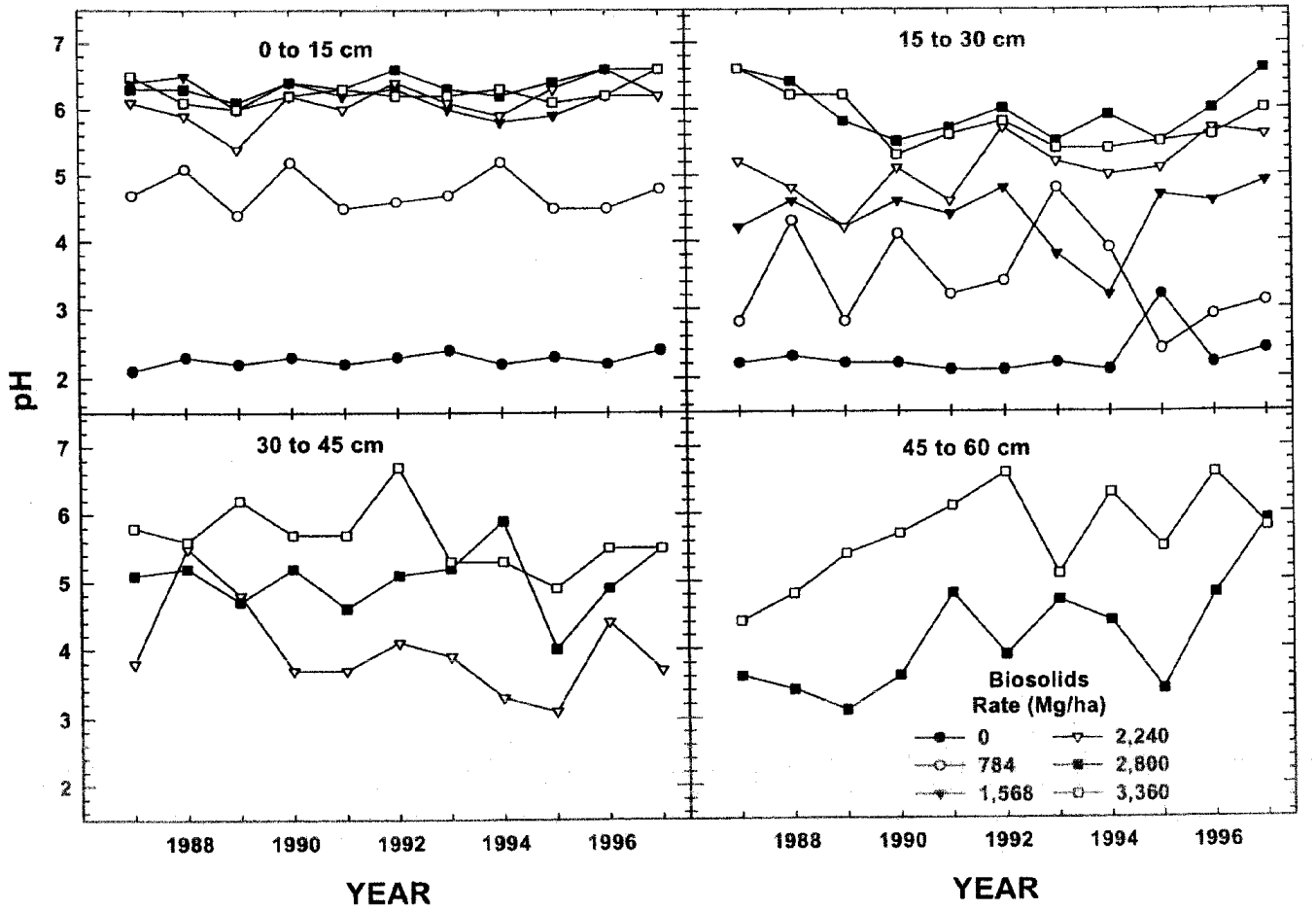
Coal Refuse pH. The effect of biosolids application on the pH of the amended coal refuse material is presented in Figures 2 and 3. The coal refuse pH in the 0- to 15- and the 15- to 30-cm depths of the unamended plot ranged between approximately 2.0 and 2.5 throughout the study, except in 1995 where the pH increased to about 3.1 (Figure 2). All amendments resulted in a pH increase at all depths of the amended coal refuse, except in 1995 at the 15- to 30-cm depth of the 784 Mg/ha unlimed biosolids treatment.

At the 0- to 15-cm depth of the treatment receiving only 784 Mg/ha biosolids amendment, the pH was much higher than in the unamended plot, fluctuating between pH 4.5 and 5.5 (Figure

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 2

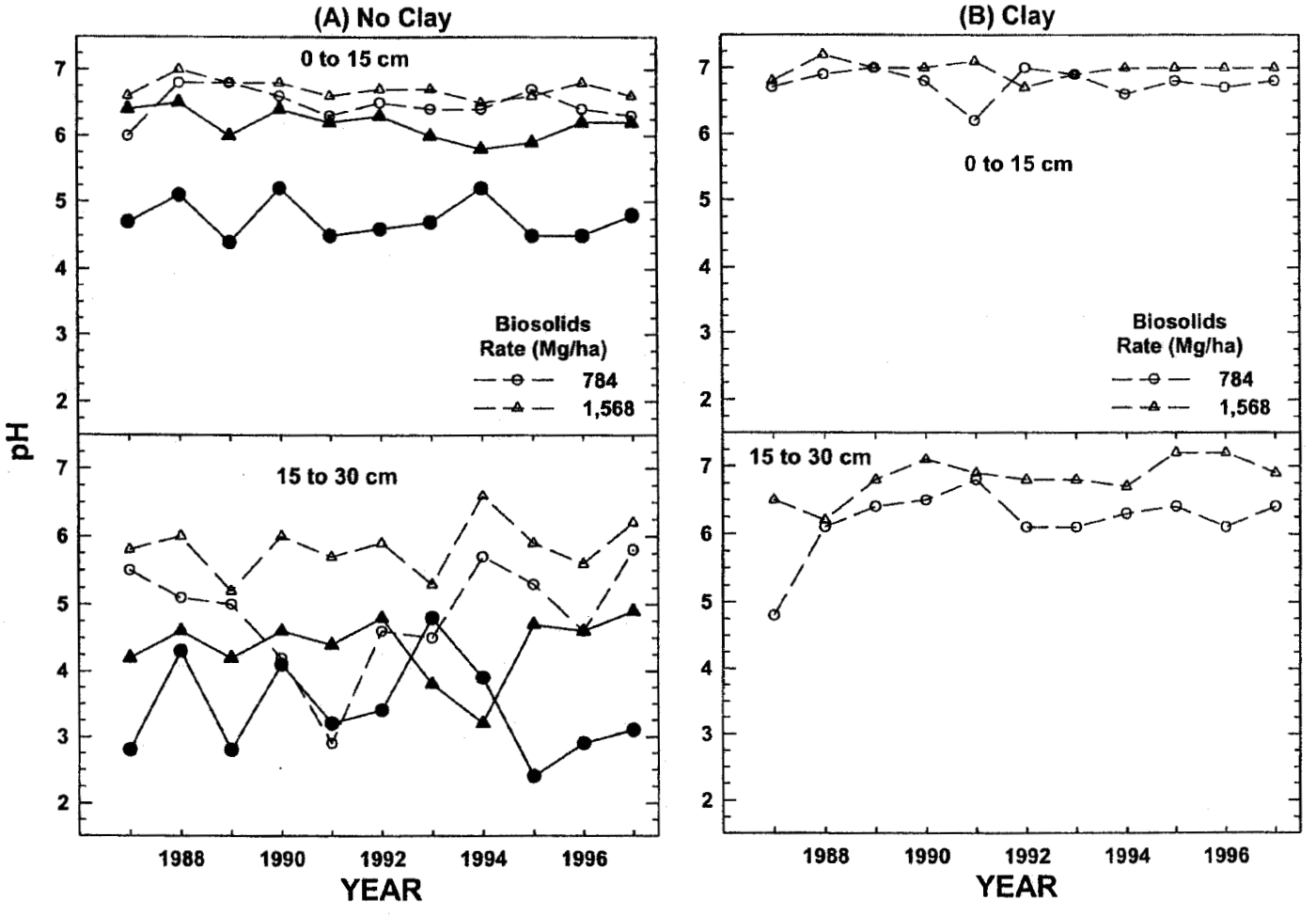
pH AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 3

pH AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



2). The pH at the 0- to 15-cm depth of the higher biosolids rates were higher than at the 784 Mg/ha biosolids rate and the values at those higher rates were similar, ranging from pH 5.5 to 6.5. Compared to the 0- to 15-cm depth, the range of coal refuse pH at the 15- to 30-cm depth were similar at 2,800 and 3,360 Mg/ha biosolids rates and was lower in the other biosolids treatments. At the lower depths (30 to 45 cm and 45 to 60 cm), coal refuse pH fluctuated but increased with biosolids loading rate. At the 45- to 60-cm depth, the coal refuse pH tended to increase with time from 1987 to 1992.

At the 784 and 1,568 Mg/ha biosolids rates, the addition of 179 Mg/ha lime was more effective than biosolids alone in increasing the coal refuse pH, and in the 0- to 15-cm depth the effect was more prominent at the 784 Mg/ha biosolids rate (Figure 3A). At the 0- to 15-cm depth, the coal refuse pH in the 1,568 Mg/ha treatment was usually only slightly lower than in the 784 Mg/ha biosolids + 179 Mg/ha lime treatment. In most years, the pH at both the 0- to 15-cm and the 15- to 30-cm depths tended to be higher in the plots treated with clay than in the plots without clay.

The effect of the treatments on increasing pH was more prominent at the upper depths of the coal refuse, where the amendments were incorporated. With time, the leaching of

biosolids constituents and Ca help to ameliorate coal refuse pH below the depth at which biosolids were incorporated. The observed liming effect of the biosolids is due to their near neutral pH (pH 6.9; Table 2) and to the neutralizing value of biosolids constituents. This agrees with observations of Griebel et al. (1979) who observed that the pH of coal refuse increased from 2.6 to 5.3 when biosolids were incorporated at rates ranging from 450 to 900 Mg/ha without lime application.

Coal Refuse Total Acidity. The total acidity in the coal refuse, estimated as the sum of sequentially extracted water-extractable and KCl-extractable acidity, is presented in Figures 4 and 5. In the unamended plot, total acidity at the 0- to 15-cm and 15- to 30-cm depths were similar and fluctuated between approximately 5 to 25 $cmol_c/kg$ (centimoles of charge per kilogram) (Figure 4). All the amendments dramatically decreased the total acidity at all amended depths of the coal refuse with the levels being generally less than 5 $cmol_c/kg$, except in a few instances where levels were higher (up to 10 $cmol_c/kg$).

At the 784 and 1,568 Mg/ha biosolids rate, total acidity in the limed and unlimed plots tended to be similar (Figure 5). In some years, the total acidity was higher in the 15- to

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FIGURE 4

TOTAL ACIDITY AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY

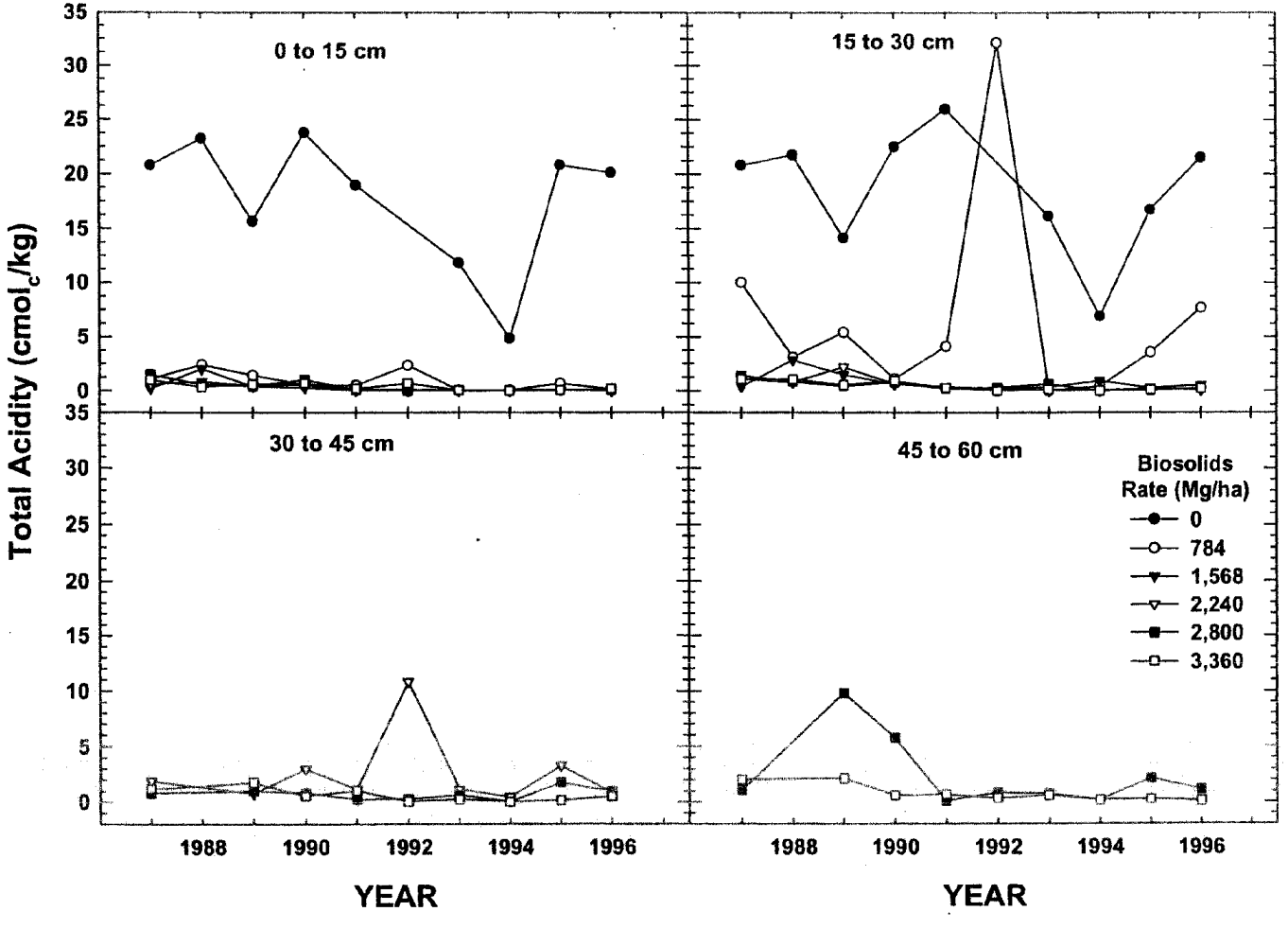

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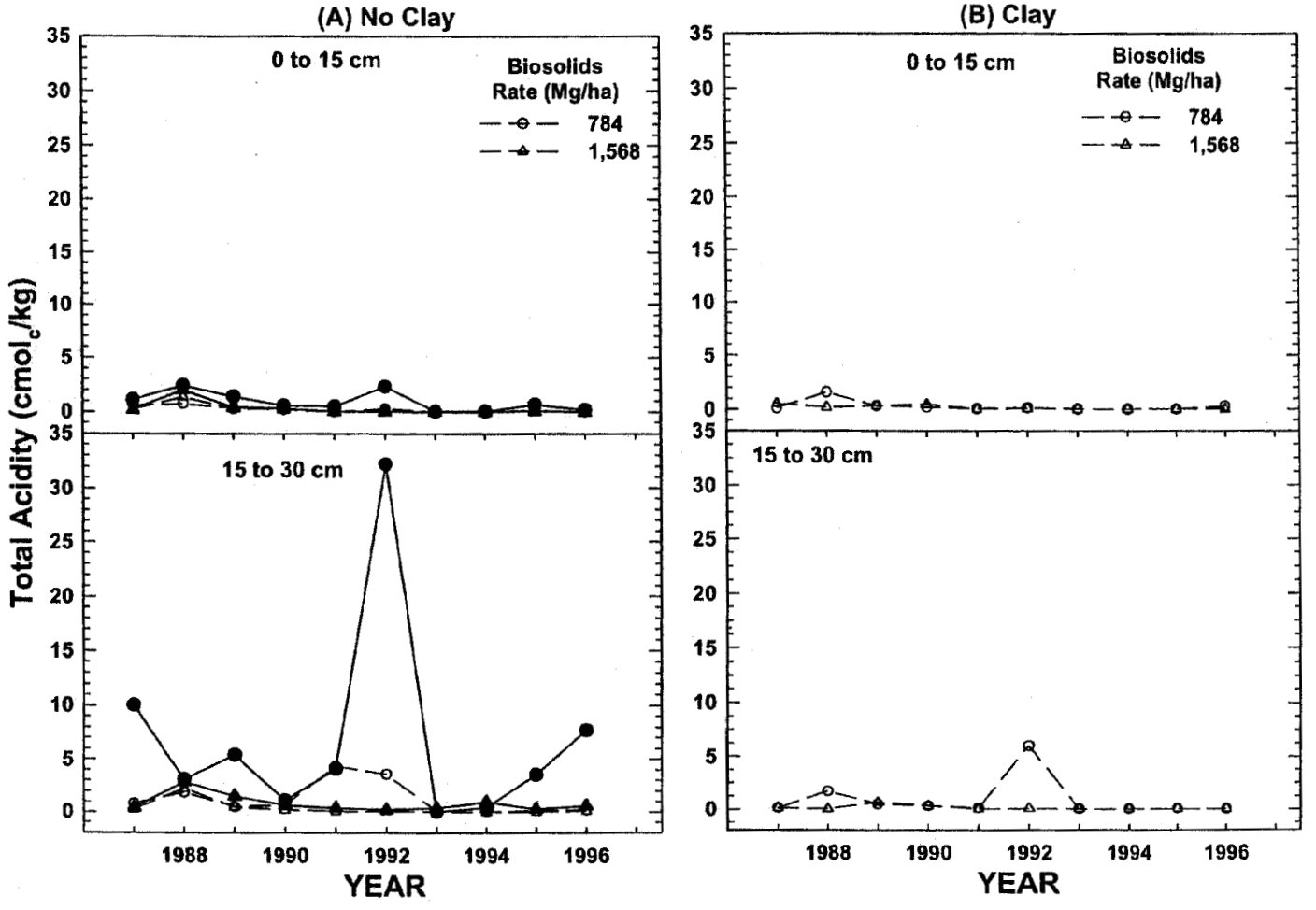
FIGURE 5

TOTAL ACIDITY AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



30-cm depth of the unlimed 784 Mg/ha biosolids treatment. There was no apparent effect of the clay treatment on the total acidity in the coal refuse (Figure 5).

WATER-EXTRACTABLE Al AND Fe IN COAL REFUSE

The concentrations of water-extractable Al in the coal refuse are presented in Figures 6 and 7, and concentrations of extractable Fe are presented in Figures 8 and 9. In the unamended plot, the concentrations of extractable Al and Fe at the 0- to 15- and 15- to 30-cm depths fluctuated during the study within a range of approximately 75 to 525 mg/kg (Figure 6) and 200 to 1,000 mg/kg (Figure 8) for Al and Fe, respectively.

In the amended plots, Fe and Al concentrations at all depths of the sampled coal refuse were much lower (usually less than 50 and 25 mg/kg, for Al and Fe, respectively), except in a few instances where higher concentrations were observed. The lower concentrations of water soluble Al and Fe in the amended plots are due to the increase in pH which reduced the solubility of Al and Fe compounds and to the sorption of these elements to the mineral and organic components of the biosolids. At the 784 and 1,568 Mg/ha biosolids rates, the unlimed plots had more instances of elevated

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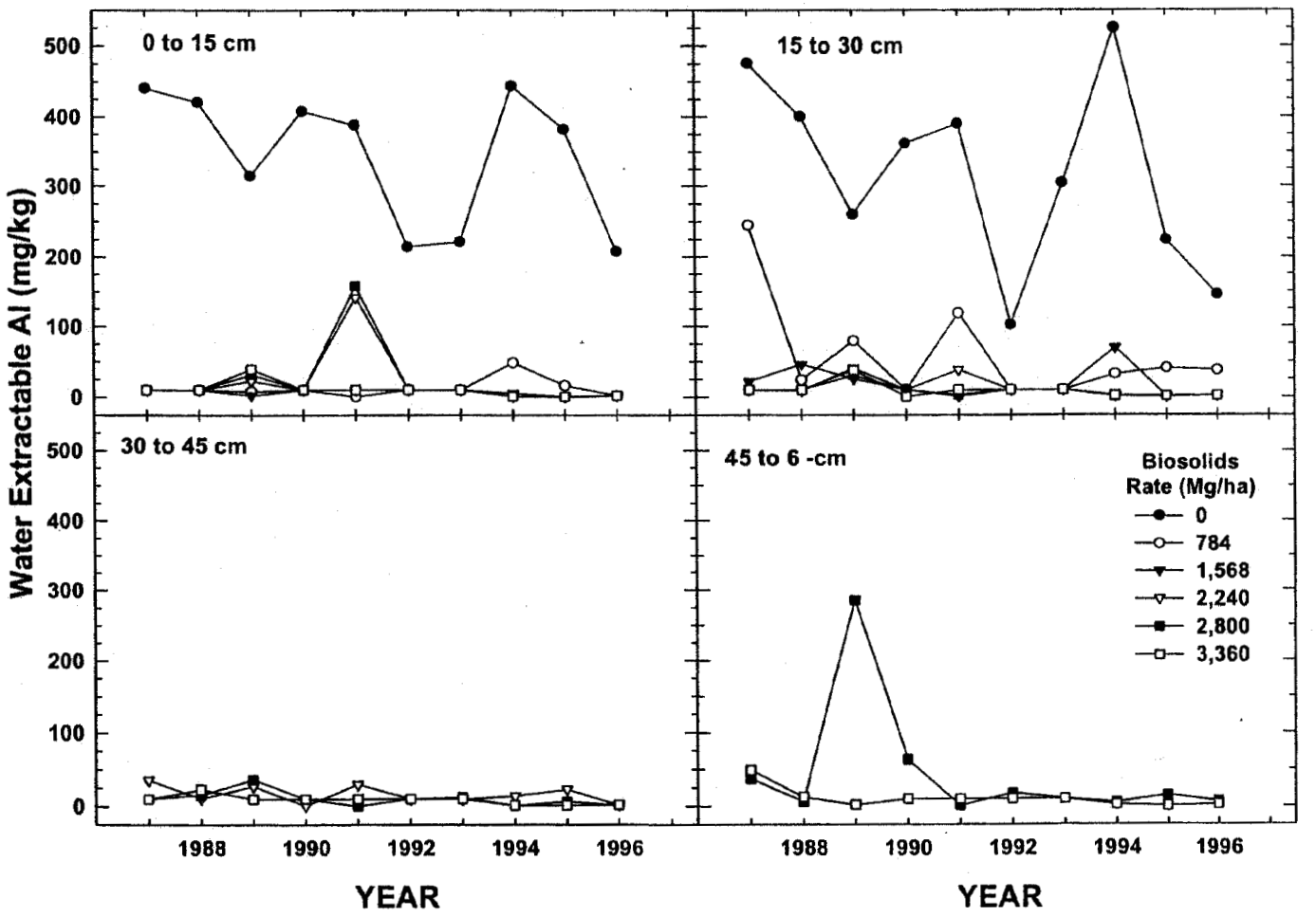
FIGURE 6

WATER EXTRACTABLE Al AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 7

WATER EXTRACTABLE Al AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY

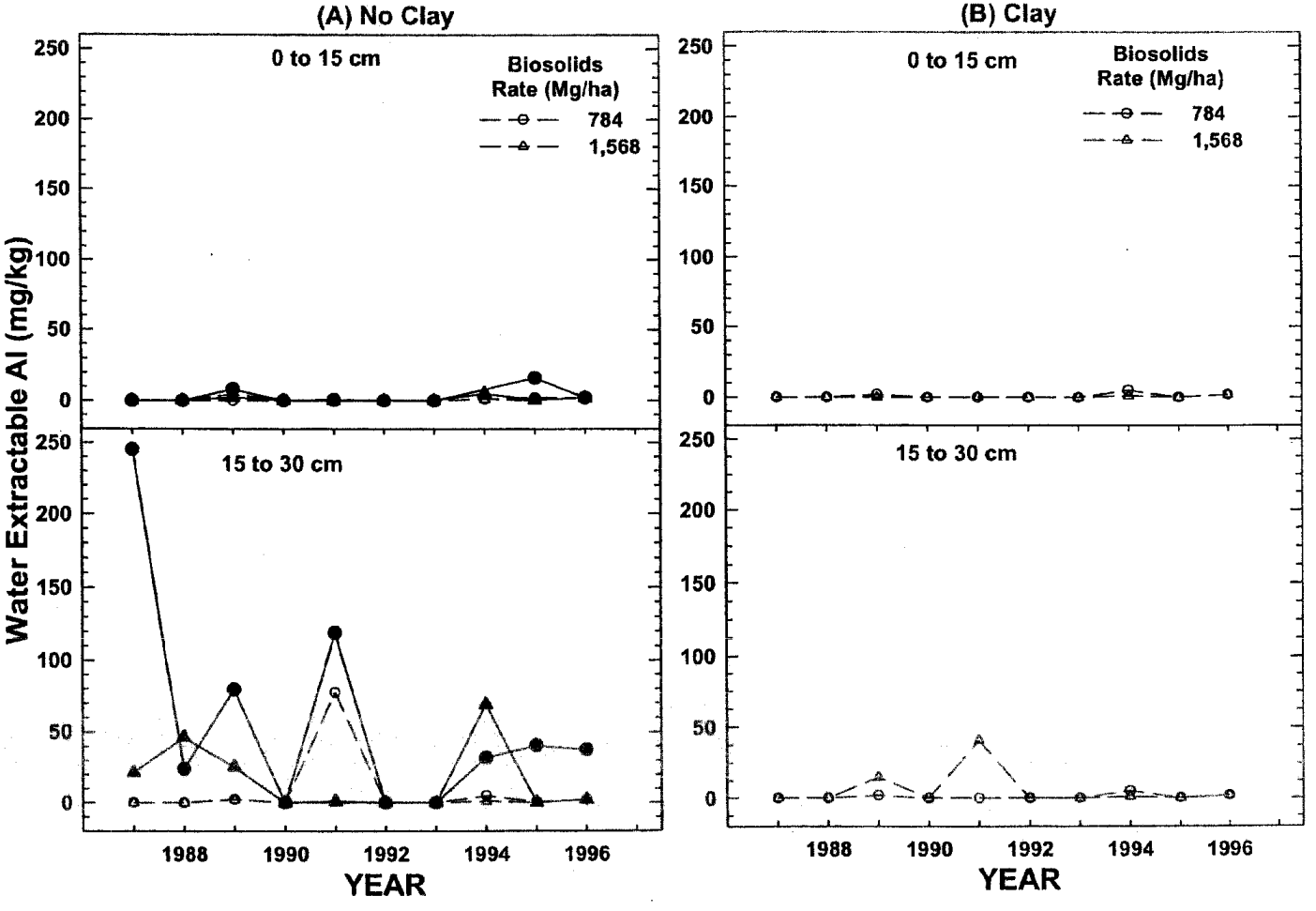


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FIGURE 8

WATER EXTRACTABLE Fe AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY

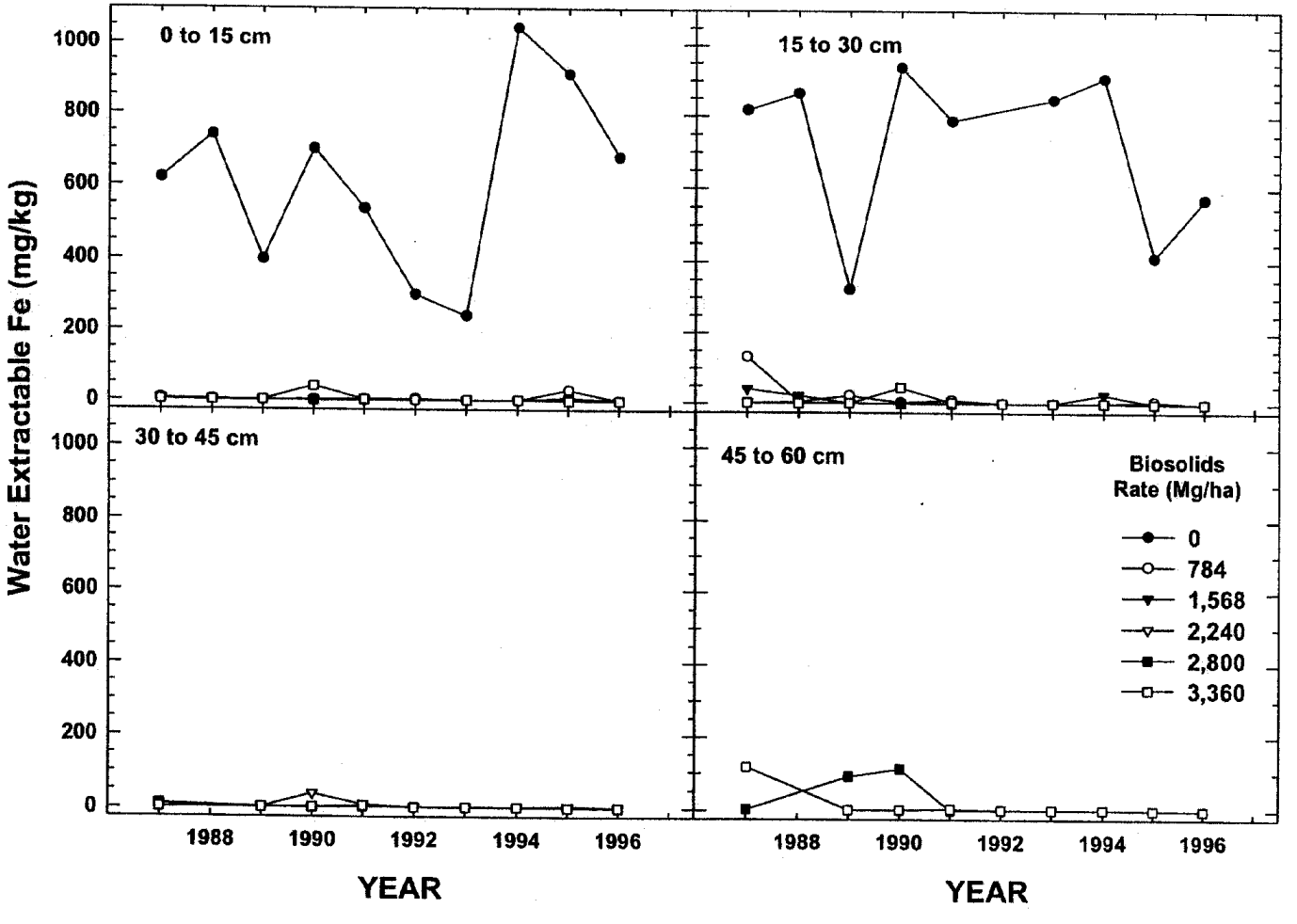

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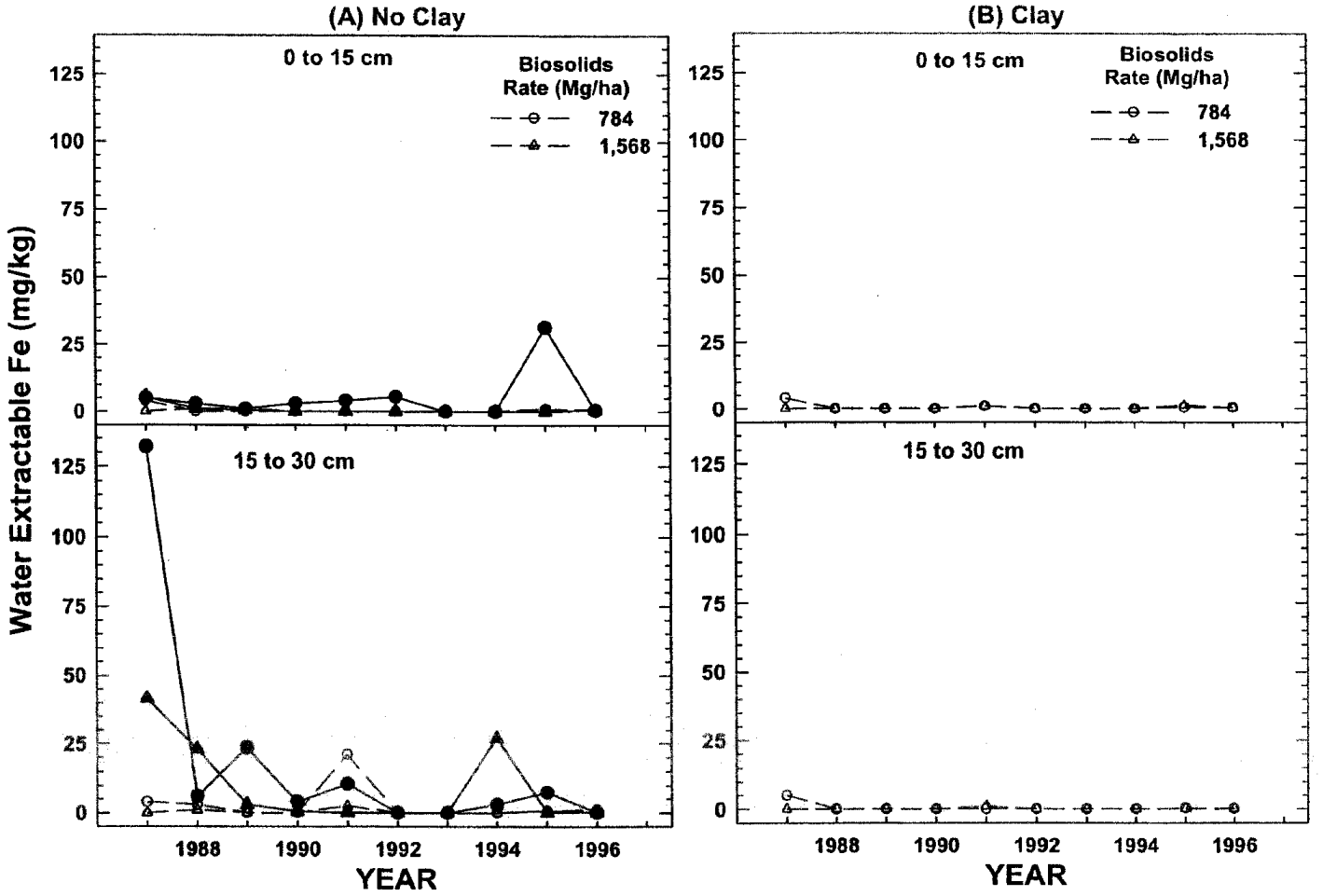
FIGURE 9

WATER EXTRACTABLE Fe AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



concentrations of water soluble Al (Figure 7) and Fe (Figure 9) than in the limed plots.

Pietz et al. (1989a) found also that a treatment of 842 Mg/ha biosolids in addition to 89.6 Mg/ha lime was more effective than biosolids alone in increasing pH and reducing total acidity and water-extractable Al and Fe of coal refuse. Except in 1991 where elevated water-extractable Al concentrations were observed at the 15- to 30-cm depth of the 784 Mg/ha biosolids treatment without clay (Figure 7A) and the 1,568 Mg/ha biosolids treatment with clay (Figure 7B), there was no apparent effect of the clay treatment on water-extractable Al and Fe.

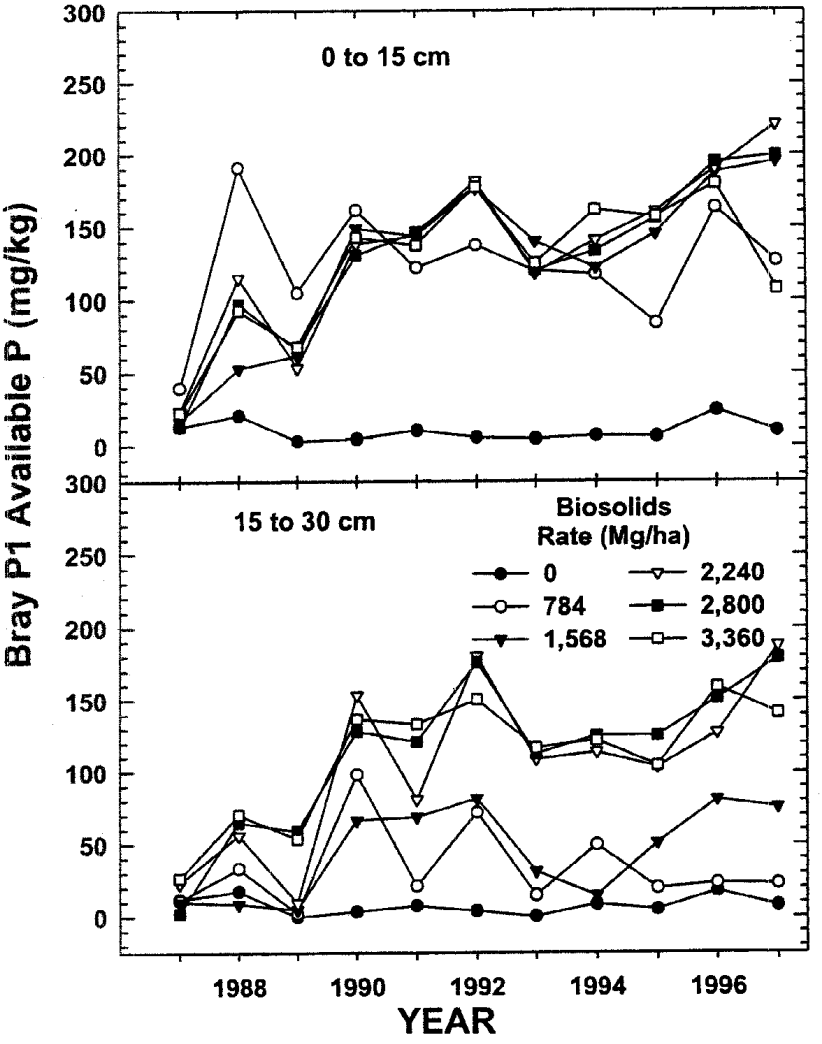
COAL REFUSE NUTRIENTS AND OTHER AGRONOMIC PARAMETERS

Available Phosphorus. The Bray P1 available P in the coal refuse is presented in Figures 10 and 11. In the 0- to 15-cm depth, available P for all the biosolids amendments fluctuated, but it tended to increase with time and was much higher than in the unamended plot. At this depth, there were also no consistent differences among the biosolids application rates. At the 15- to 30-cm depth, available P at the 784 and 1,568 Mg/ha biosolids rates tended to be much lower than at

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 10

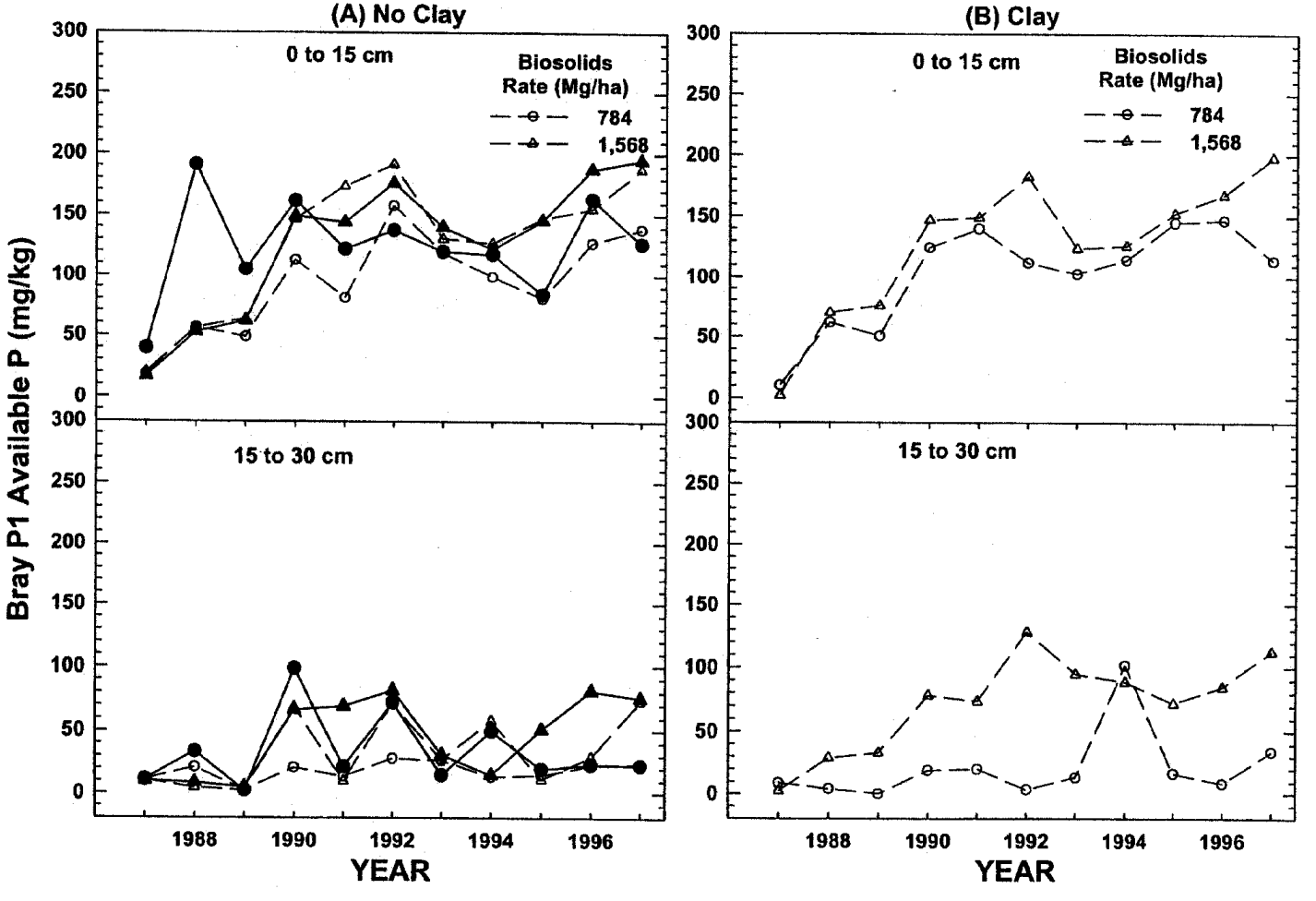
BRAY P1 AVAILABLE P AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 11

BRAY P1 AVAILABLE P AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



the higher biosolids rates. At the 784 and 1,568 Mg/ha biosolids rates, there were no consistent effects of the lime treatment except in the 15- to 30-cm depth of the 1,568 Mg/ha biosolids plot amended with clay in which the available P in most years tended to be higher than in the plot receiving no clay (Figure 11).

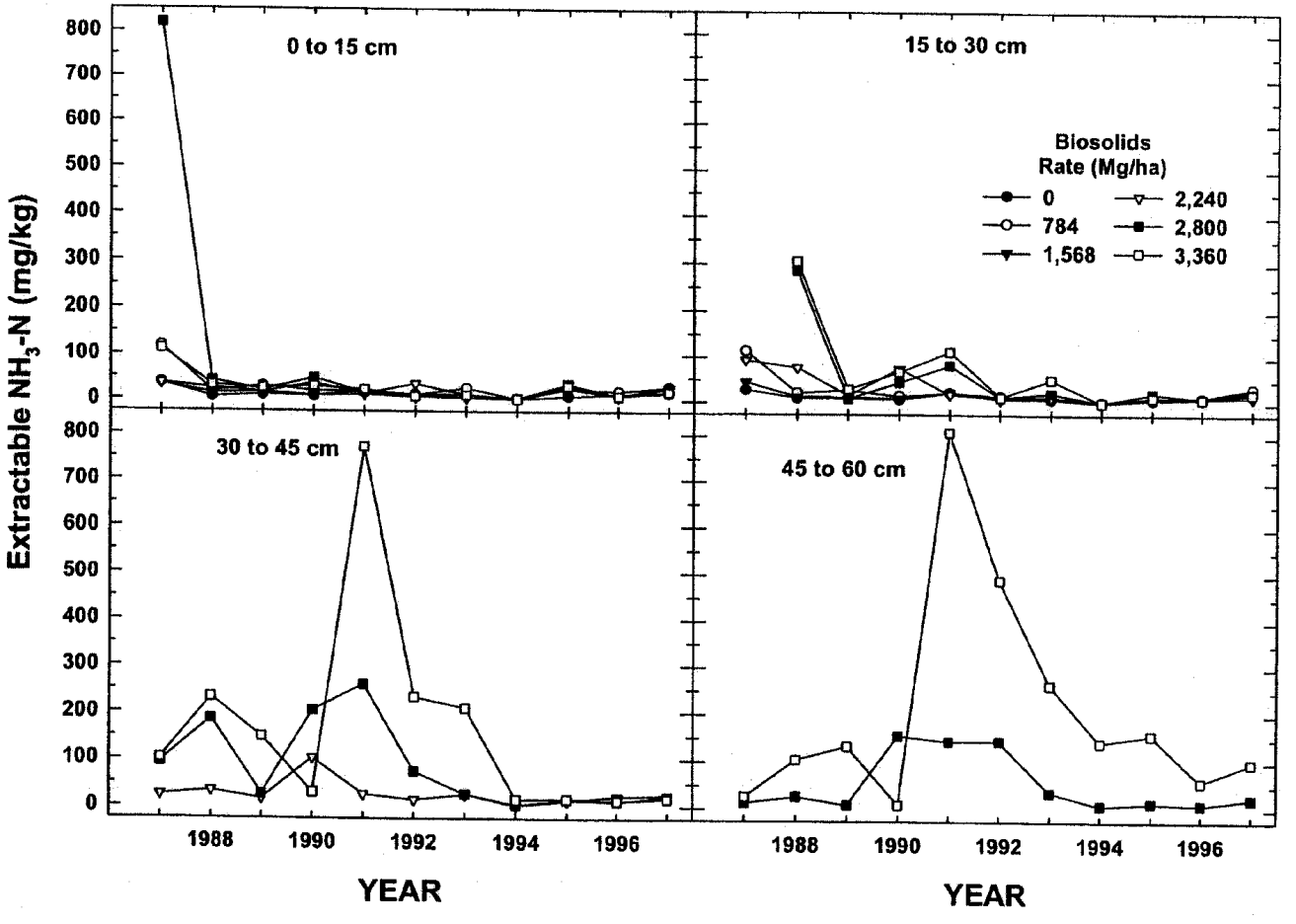
Extractable Ammonia- and Nitrate-Nitrogen. The concentrations of extractable NH_3-N in the coal refuse are presented in Figures 12 and 13. At the 0- to 15-cm depth, except for the higher levels observed for some of the treatments in 1987, the NH_3-N levels were similar and usually less than 50 mg/kg. At the lower depths, there was greater fluctuation in NH_3-N concentrations. The fluctuations were most likely due to variations in the transformation of N species associated with mineralization of organic N to NH_3-N and the nitrification of NH_3-N to NO_3-N. There were very little differences between concentrations of NH_3-N in the limed and unlimed treatments (Figure 13). Except in 1997 where NH_3-N concentration at the 768 Mg/ha biosolids in the plot receiving no clay was elevated, there was no apparent effect of the clay treatment.

The concentrations of extractable NO_3-N in the coal refuse are presented in Figures 14 and 15. At the 0- to 15-cm

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 12

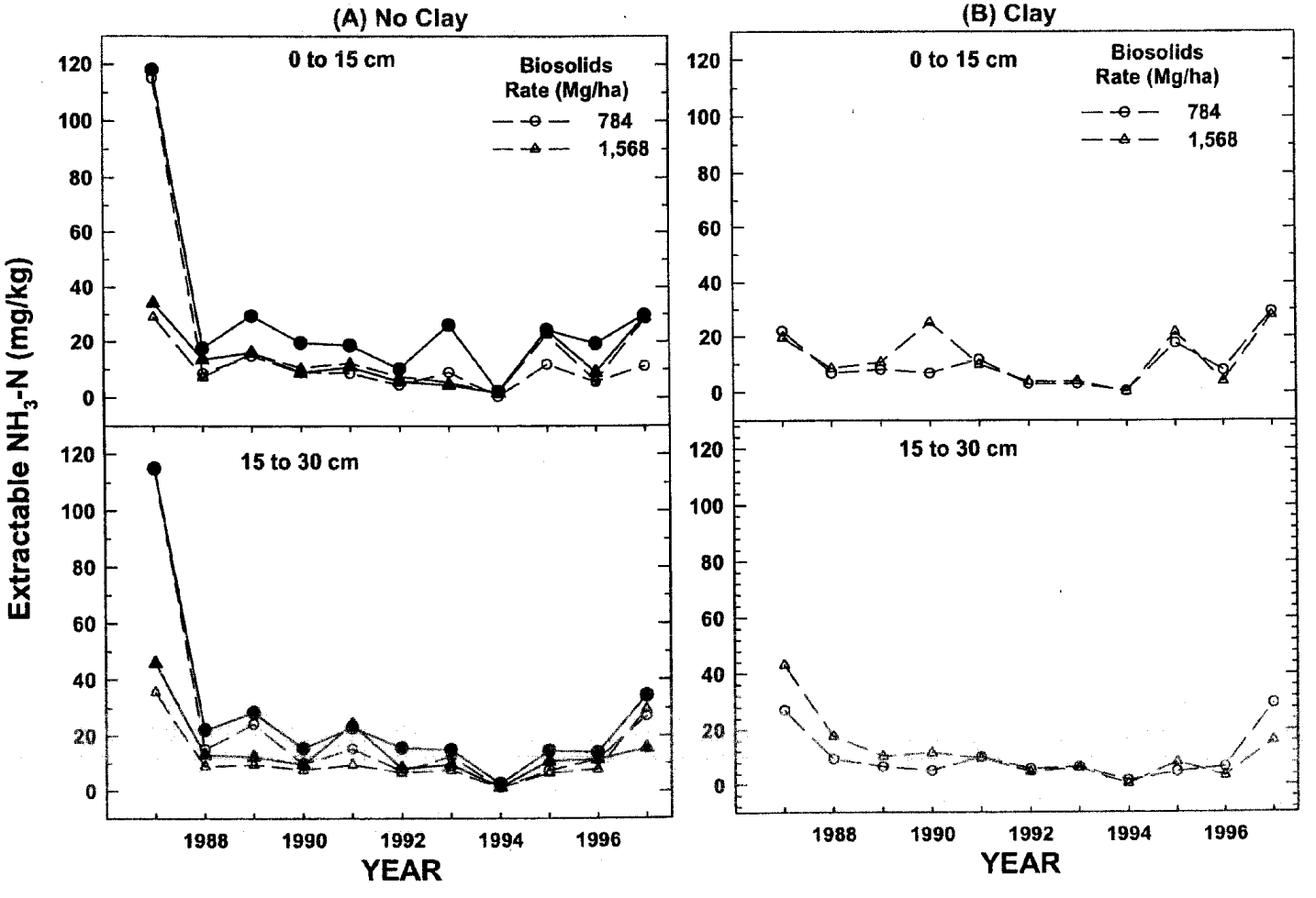
EXTRACTABLE NH_3-N AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 13

EXTRACTABLE NH_3-N AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 14

EXTRACTABLE NO_3-N AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY

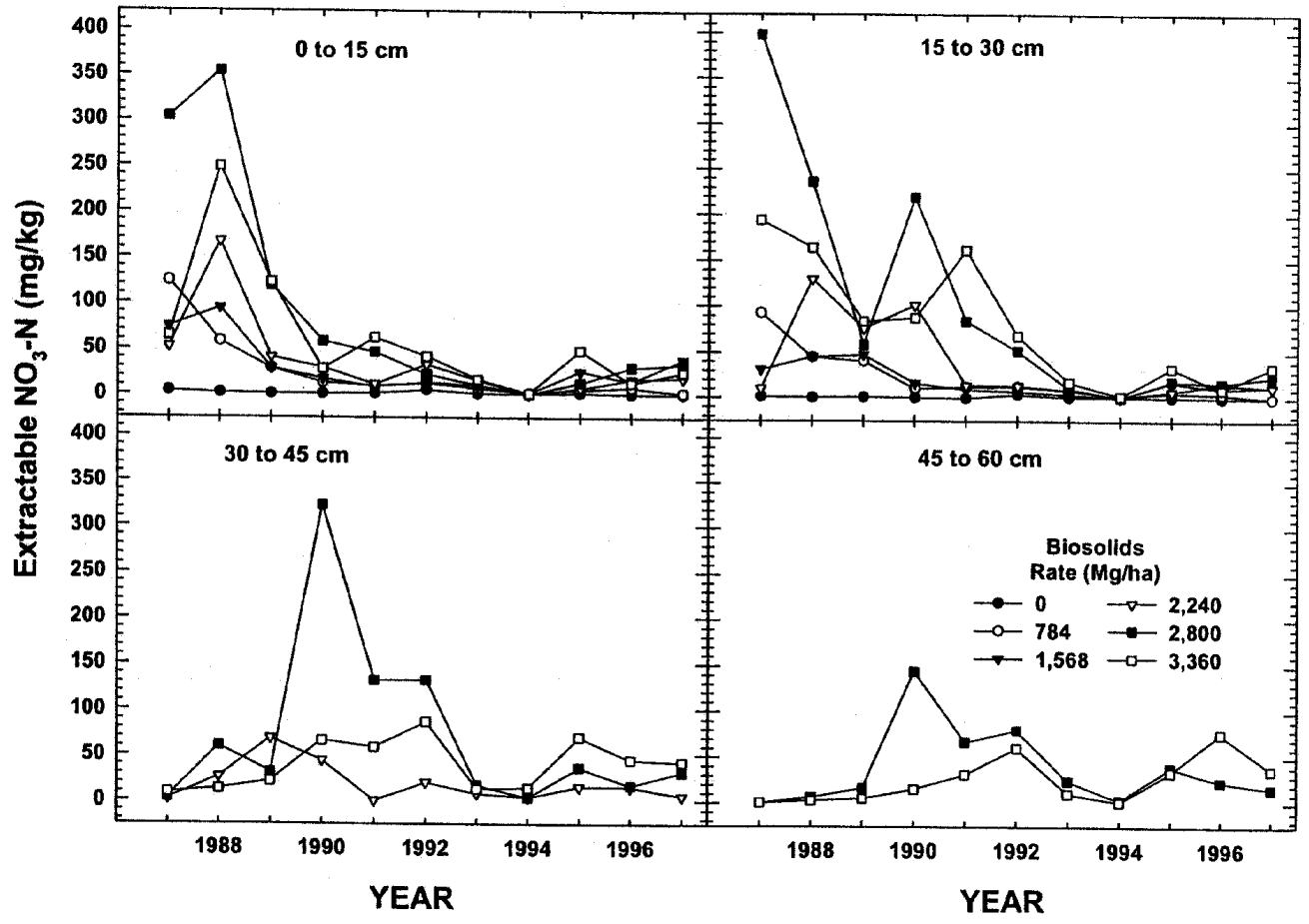


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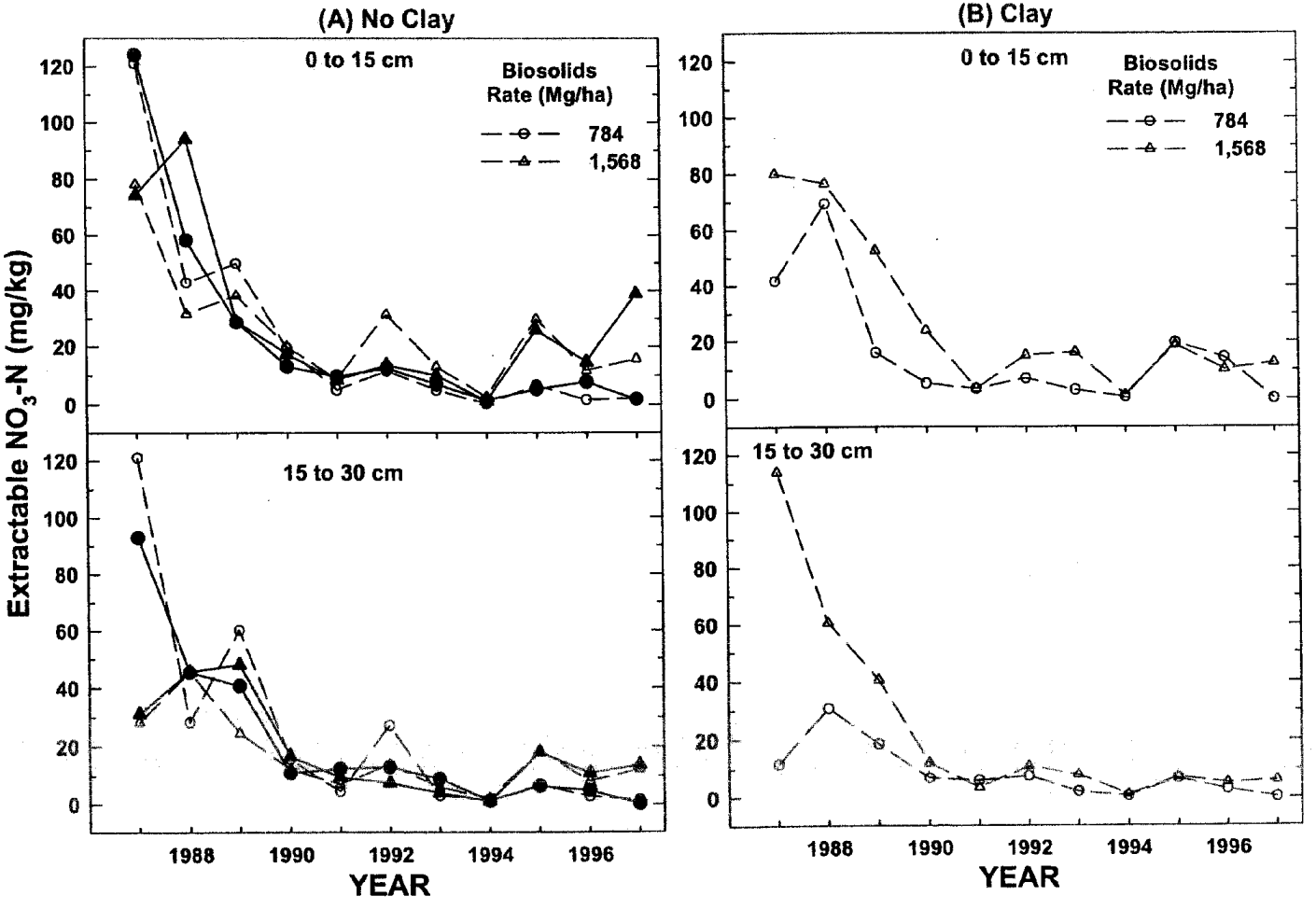
FIGURE 15

EXTRACTABLE NO_3-N AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



and 15- to 30-cm depths, NO_3-N concentrations rose during the first year, then declined rapidly from levels as high as 400 mg/kg to nearly constant levels of less than 60 mg/kg by 1993. At the lower depths, the NO_3-N concentrations fluctuated but tended to increase above the 1987 levels. The increase in NO_3-N at the lower depths is due partly to nitrification at those depths and vertical movement of NO_3-N from the upper depths. There were no consistent differences between concentrations of NO_3-N in the limed and unlimed treatments and between the clay and nonclay treatments (Figure 15).

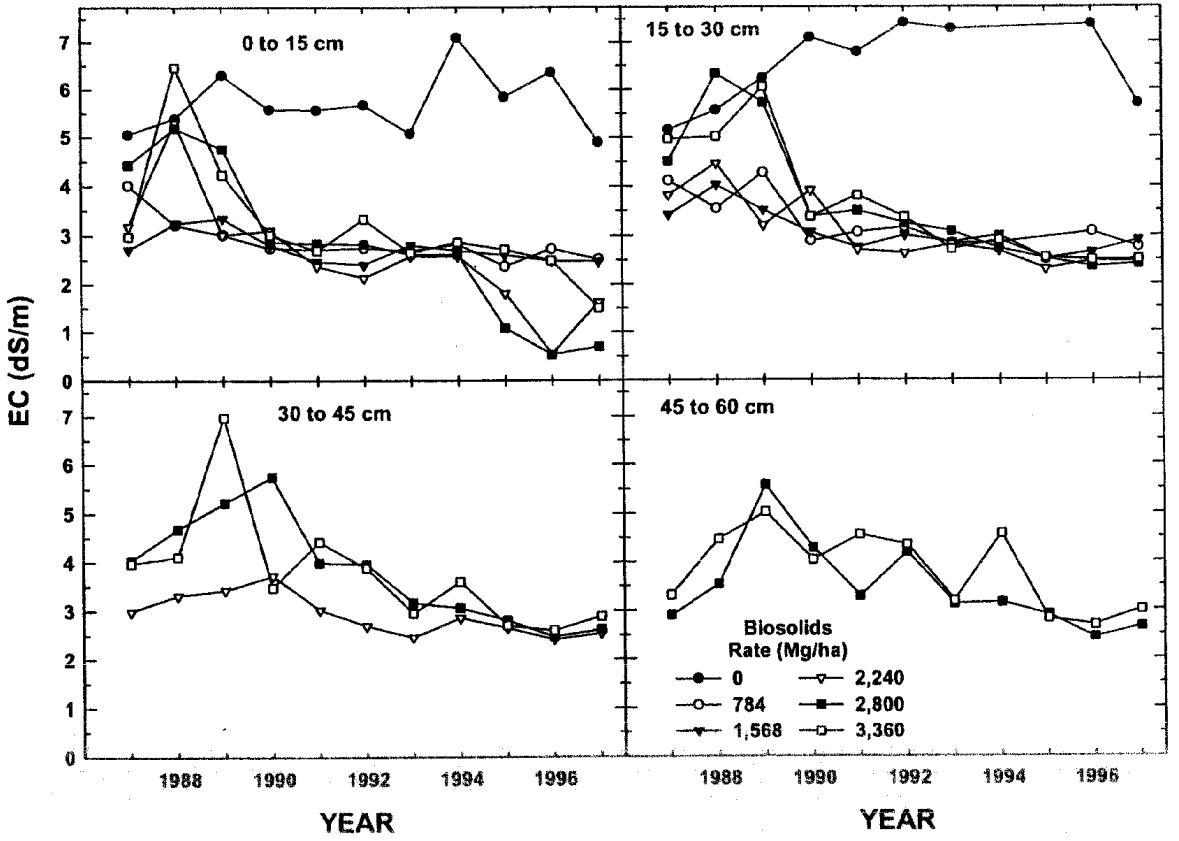
Salinity. Soil salinity is a measure of the soluble salt content in soils, and it is usually measured as electrical conductivity (EC) of the soil extract. The EC in the coal refuse is presented in Figures 16 and 17. There were no consistent differences between the biosolids treatments. For most of the treatments, the EC at the 0- to 15-cm and 15- to 30-cm depths increase in the first two years and then declined sharply afterwards to nearly constant levels between 2.5 and 3.5 dS/m (Figure 16).

From 1994 to the end of the study, much lower EC values were observed at the 0- to 15-cm and 15- to 30-cm depths for the 2,240 and 2,800 Mg/ha biosolids rates. Except, in the

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 16

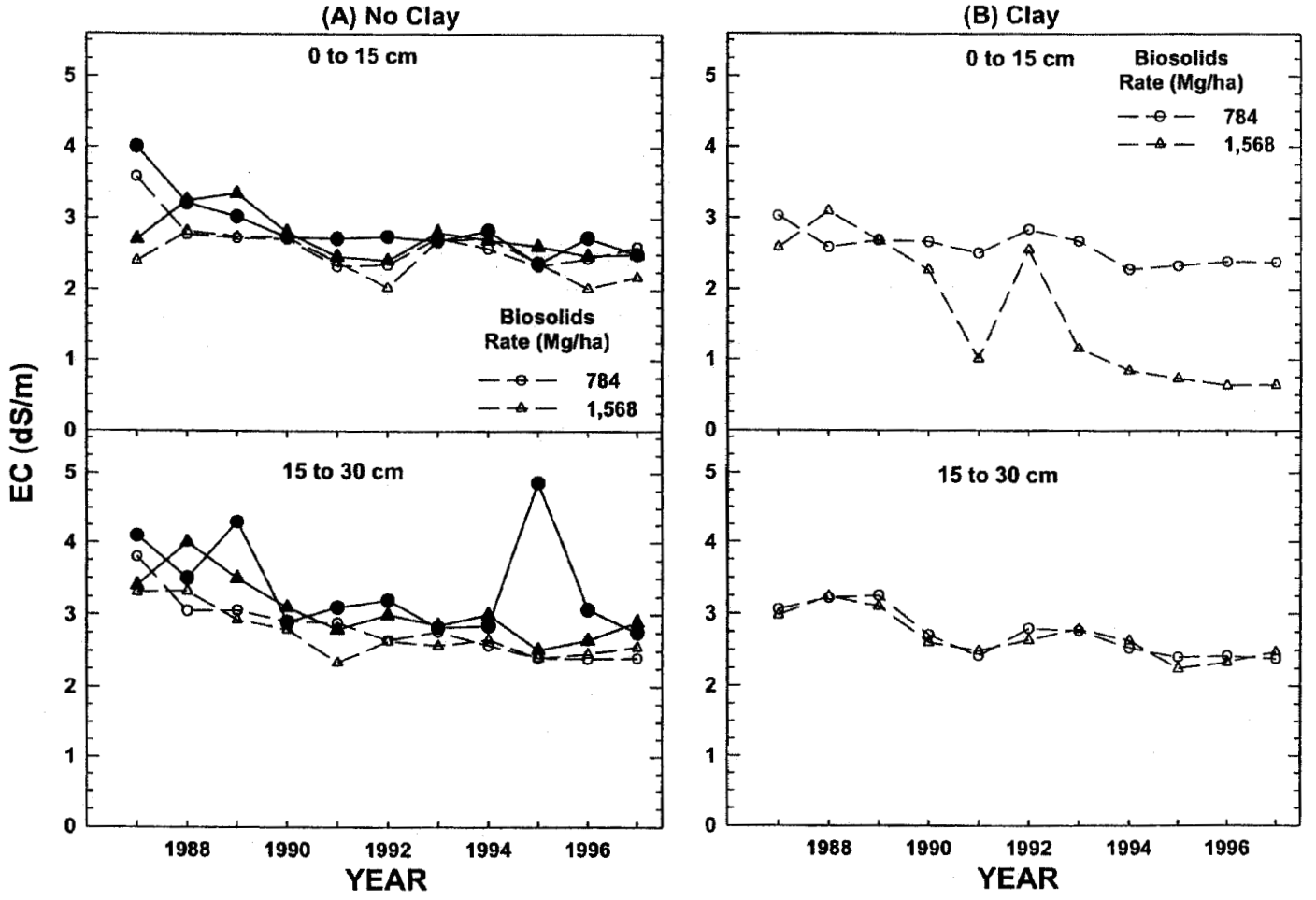
ELECTRICAL CONDUCTIVITY (EC) AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 17

ELECTRICAL CONDUCTIVITY (EC) AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



first three years, the EC at those two depths in the unamended plot was always much higher than in the amended plots, and it fluctuated between approximately 5 and 7.5 dS/m. This salinity in the unamended plot is quite unsuitable for the growth of most plants. Soil EC > 3.2 dS/m is rated as strongly saline, and it can limit the growth and performance of cover vegetation such as that used at St. David (Soil and Plant Analysis Council, 1999).

At the 30- to 45-cm and 45- to 60-cm depths, the EC tended to increase during the initial two to three years, and then it declined to near constant levels of approximately 2.5 to 3.0 dS/m by the end of the study. At the 784 and 1,568 Mg/ha biosolids rates, the coal refuse EC tended mostly to be higher in the unlimed treatments than in the limed treatments (Figure 17A). The EC in the clay-amended plots (Figure 17B) tended to be similar to the plots receiving no clay, except in the 0- to 15-cm depth of the 1,568 Mg/ha biosolids rate where the EC was much lower in 1991 and the period from 1993 to the end of the study.

Water-Soluble and Exchangeable K, Ca, Mg, and Na. The summary of water-soluble K, Ca, Mg and Na is presented in Tables 3 and 4. The summary of exchangeable K, Ca, and Mg and

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 3

SUMMARY OF WATER SOLUBLE BASES DURING TEN YEARS AT THREE DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY

Biosolids (Mg/ha)	Soil Depth (cm) 0 to 15			15 to 30			30 to 45[1]		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
	Water Soluble K (mg/kg)								
0	<0.1	31	9	2.0	105	15			
784	12	113	53	2.0	46	25			
1,568	24	144	73	3.0	87	30			
2,240	50	242	131	18	129	64	6.0	76	36
2,800	70	296	134	43	297	121	4.6	102	69
3,360	33	262	133	5.6	268	108	2.2	252	97
	Water Soluble Ca (mg/kg)								
0	2,305	9,381	6,432	2,160	8,986	6,166			
784	5,444	9,011	7,036	5,322	9,205	6,927			
1,568	3,390	8,181	6,116	4,832	8,866	6,839			
2,240	596	8,875	4,657	5,939	8,750	7,238	5,345	9,455	7,120
2,800	233	7,955	3,961	2,955	10,080	6,693	5,799	10,365	7,523
3,360	2,653	9,415	5,916	4,723	11,185	7,040	5,310	8,918	6,947

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 3 (Continued)

SUMMARY OF WATER SOLUBLE BASES DURING TEN YEARS AT THREE DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY

Biosolids (Mg/ha)	Soil Depth (cm) 0 to 15			15 to 30			30 to 45[1]		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
	Water Soluble Mg (mg/kg)								
0	136	365	220	128	332	197			
784	238	1,150	535	175	847	423			
1,568	198	832	436	228	1,057	599			
2,240	101	1,155	528	290	937	592	197	634	383
2,800	64	1,154	513	264	1,244	773	463	1,464	804
	Water Soluble Na (mg/kg)								
0	<0.1	23	5	<0.1	29	6.6			
784	<0.1	80	18	<0.1	26	11			
1,568	<0.1	68	15	<0.1	25	10			
2,240	3.2	156	46	6.8	96	41	<0.1	31	15
2,800	2.9	178	56	10	181	78	<0.1	83	53
3,360	<0.1	164	57	<0.1	171	74	9.2	145	64

[1]The 0, 784, and 1,568 Mg/ha biosolids treatments were not monitored at the 30- to 45-cm depth.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 4

SUMMARY OF WATER SOLUBLE BASES DURING TEN YEARS AT THREE DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS + LIME[1]

Biosolids (Mg/ha)	Soil Depth (cm) 0 to 15			15 to 30			30 to 45[2]		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
	Water Soluble K (mg/kg)								
784	20	117	59	5.5	33	21			
1,568	48	341	128	17	137	50	21	87	38
	Water Soluble Ca (mg/kg)								
784	2,521	9,615	6,112	5,245	9,591	6,750			
1,568	405	9,220	3,941	4,163	10,320	7,140	6,325	8,961	7,305
	Water Soluble Mg (mg/kg)								
784	127	660	305	93	652	315			
1,568	58	650	298	148	770	393	183	657	370
	Water Soluble Na (mg/kg)								
784	<0.1	73	13	0.1	33	8.5			
1,568	<0.1	87	18	0.1	54	16	<0.1	17	8.6

[1]Lime application rate = 179 Mg/ha.
[2]The 784 Mg/ha biosolids treatment was not monitored at the 30- to 45-cm depth.

exchangeable sodium percentage (ESP) is presented in Tables 5 and 6. For plots amended with the 784 and 1,568 Mg/ha biosolids rates plus lime, the data for the plots with and without clay were summarized as the mean of those biosolids plus lime treatments (Tables 4 and 6) because there were no apparent differences in the water-soluble and exchangeable constituents between the plots with and without clay. For brevity, data for the 45- to 60-cm depth are not included in the summary. Exchangeable sodium percentage was calculated as the molar ratio of exchangeable Na to the sum of exchangeable Ca and Mg using the formula:

$$ESP = Na^+/(\text{sum of } Ca^{2+},\ Mg^{2+},\ K^+,\ Na^+,\ \text{and } NH_4^+) \quad \text{Eq. 1}$$

where all cations are in units of $cmol_c/kg$.

In the unlimed treatments, mean water-soluble (Table 3) and exchangeable (Table 5) K and Mg increased with biosolids rate. There was no consistent effect of biosolids on mean concentrations of water-soluble Ca (Tables 3 and 4), but exchangeable Ca tended to decrease with biosolids rate (Tables 5 and 6). At the 784 and 1,568 Mg/ha biosolids rates, water-soluble Ca tended to be lower in the limed plots compared to the unlimed plots (Table 4). There were no consistent effects of the lime amendment on the water-extractable or exchangeable levels of the other basic cations.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 5

SUMMARY OF EXCHANGEABLE BASES AND EXCHANGEABLE SODIUM PERCENTAGE DURING TEN YEARS AT THREE DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY

Biosolids (Mg/ha)	Soil Depth (cm) 0 to 15 Minimum	0 to 15 Maximum	0 to 15 Mean	15 to 30 Minimum	15 to 30 Maximum	15 to 30 Mean	30 to 45[1] Minimum	30 to 45[1] Maximum	30 to 45[1] Mean
				Exchangeable K (mg/kg)					
0	16	379	62	14	173	40			
784	8	293	159	47	670	131			
1,568	146	412	241	35	124	71			
2,240	149	629	397	81	306	165	42	1,017	163
2,800	58	710	430	202	691	369	81	1,127	275
3,360	34	652	413	150	543	274	113	290	202
				Exchangeable Ca (mg/kg)					
0	3,875	38,943	23,927	4,105	55,650	29,340			
784	3,966	64,517	23,799	4,331	44,228	24,543			
1,568	3,927	57,167	16,941	4,629	62,067	28,272			
2,240	2,198	39,900	14,209	4,510	57,050	23,906	4,862	56,467	29,650
2,800	2,403	59,967	13,726	3,122	70,933	20,354	3,962	67,083	26,598
3,360	3,462	33,133	12,878	4,818	27,084	21,773	4,574	38,407	22,707

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 5 (Continued)

SUMMARY OF EXCHANGEABLE BASES AND EXCHANGEABLE SODIUM PERCENTAGE DURING TEN YEARS AT THREE DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY

Biosolids (Mg/ha)	Soil Depth (cm) 0 to 15			15 to 30			30 to 45[1]		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
	Exchangeable Mg (mg/kg)								
0	118	861	270	106	912	277			
784	292	1,575	563	139	1,584	496			
1,568	304	1,042	641	229	736	493			
2,240	385	1,609	781	247	1,049	599	175	1,071	453
2,800	375	1,529	832	222	1,430	874	181	1,118	712
3,360	180	1,575	828	329	1,744	886	322	1,076	682
	ESP[2]								
0	0.02	0.48	0.18	0.02	0.29	0.1			
784	0.03	1.5	0.27	0.03	0.5	0.17			
1,568	0.06	1.2	0.31	0.03	0.5	0.12			
2,240	0.06	2.0	0.5	0.05	1.7	0.31	0.03	0.5	0.14
2,800	0.07	2.5	0.7	0.24	2.4	0.6	0.04	1.5	0.33
3,360	0.02	2.5	0.6	0.11	2.2	0.5	0.07	1.5	0.4

[1]The 0, 784, and 1,568 Mg/ha biosolids treatments were not monitored at the 30- to 45-cm depth.
[2]ESP = Exchangeable sodium percentage = Exchangeable Na^+/(sum of exchangeable Ca^{2+}, Mg^{2+}, K^+, Na^+, and NH_4^+). All cations are in units of $cmol_c/kg$.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 6

SUMMARY OF EXCHANGEABLE BASES AND EXCHANGEABLE SODIUM PERCENTAGE DURING TEN YEARS AT THREE DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS + LIME[1]

Biosolids (Mg/ha)	Soil Depth (cm) 0 to 15			15 to 30			30 to 45[2]		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
	Exchangeable K (mg/kg)								
784	113	986	224	14	673	106			
1,568	129	778	294	50	496	125	52	488	119
	Exchangeable Ca (mg/kg)								
784	4,163	58,683	16,064	4,388	70,233	27,779			
1,568	2,131	47,950	11,679	4,691	53,317	22,806	5,123	38,033	25,089
	Exchangeable Mg (mg/kg)								
784	183	1598	519	113	1,576	382			
1,568	199	1706	577	138	1,430	479	151	830	420
	ESP[3]								
784	0.07	1.53	0.33	0.03	0.6	0.14			
1,568	0.04	1.59	0.41	0.01	1.23	0.22	0.02	0.49	0.15

[1]Lime application rate = 179 Mg/ha.

[2]The 784 Mg/ha biosolids treatment was not monitored at the 30- to 45-cm depth.

[3]ESP = Exchangeable sodium percentage = Exchangeable Na^+/(sum of exchangeable Ca^{2+}, Mg^{2+}, K^+, Na^+ and NH_4^+). All cations are in units of $cmol_c/kg$.

Exchangeable sodium percentage (ESP) is a measure of the relative dominance of Na on cation exchange sites and is calculated as the molar ratio of Na to the cation exchange capacity (CEC) or the sum of exchangeable cations. The physical structure of soils decreases as ESP increases, and at ESP greater than 15 soils are classified as "Sodic". Sodic soils have poor structure and water transmission characteristics.

Exchangeable sodium percentage tended to decrease with depth in coal refuse and increase as biosolids rate increased (Tables 5 and 6). The maximum ESP observed was 2.5, in the 0- to 15-cm depth of the 2,800 and 3,360 Mg/ha treatments. The ESP in the treatments of 784 and 1,568 Mg/ha biosolids (Table 5) were quite similar to the treatments receiving those biosolids rates plus 179 Mg/ha lime (Table 6).

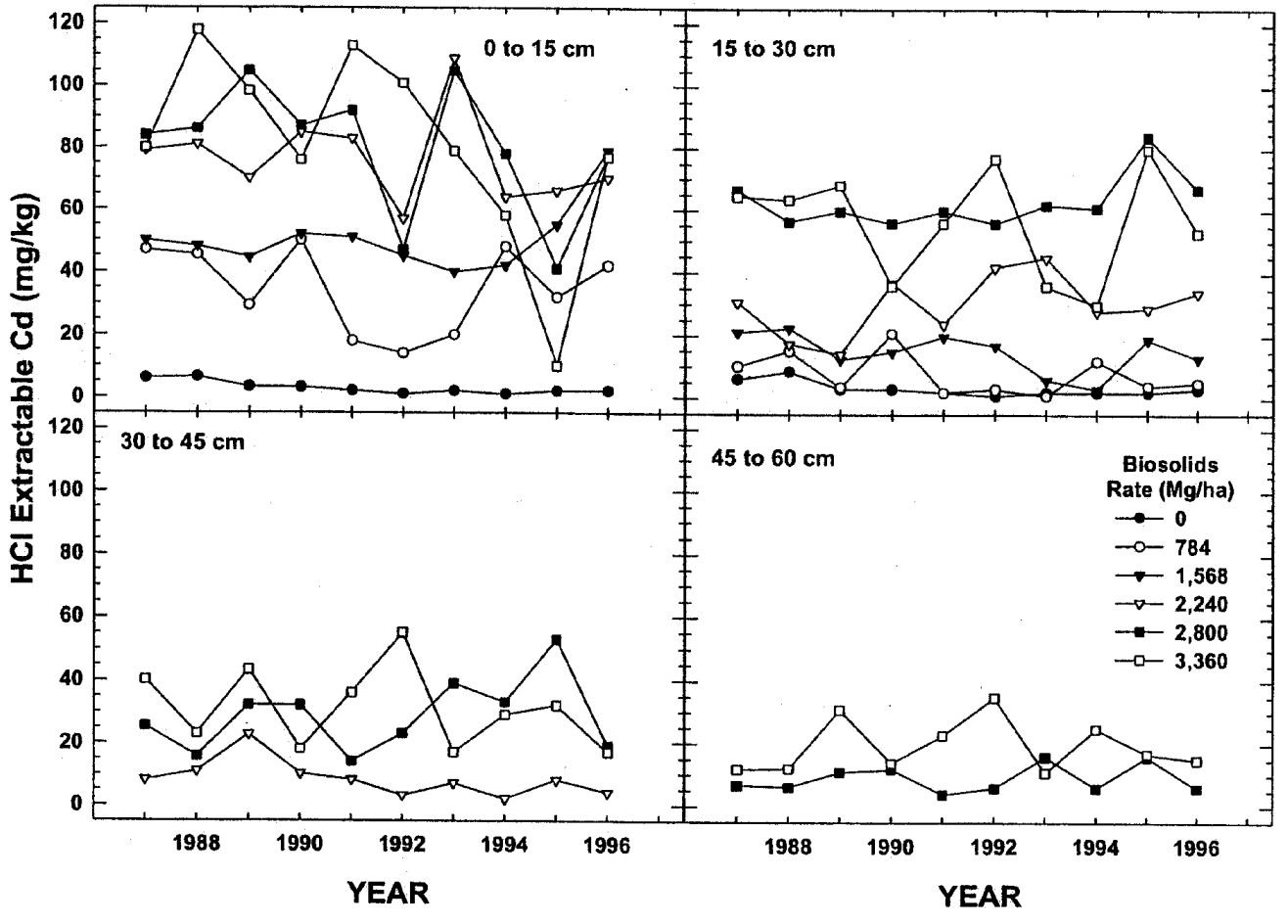
HCl-EXTRACTABLE METALS IN COAL REFUSE

HCl-Extractable Cadmium. The concentrations of HCl-extractable Cd in the coal refuse are presented in Figures 18 and 19. In all the plots, HCl-extractable Cd fluctuated throughout the study and tended to decrease with depth in the coal refuse. At the 0- to 15-cm depth, extractable Cd concentrations in the unamended plots were always lower than in the amended plots (Figure 18). At the 0- to 15-cm depth,

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 18

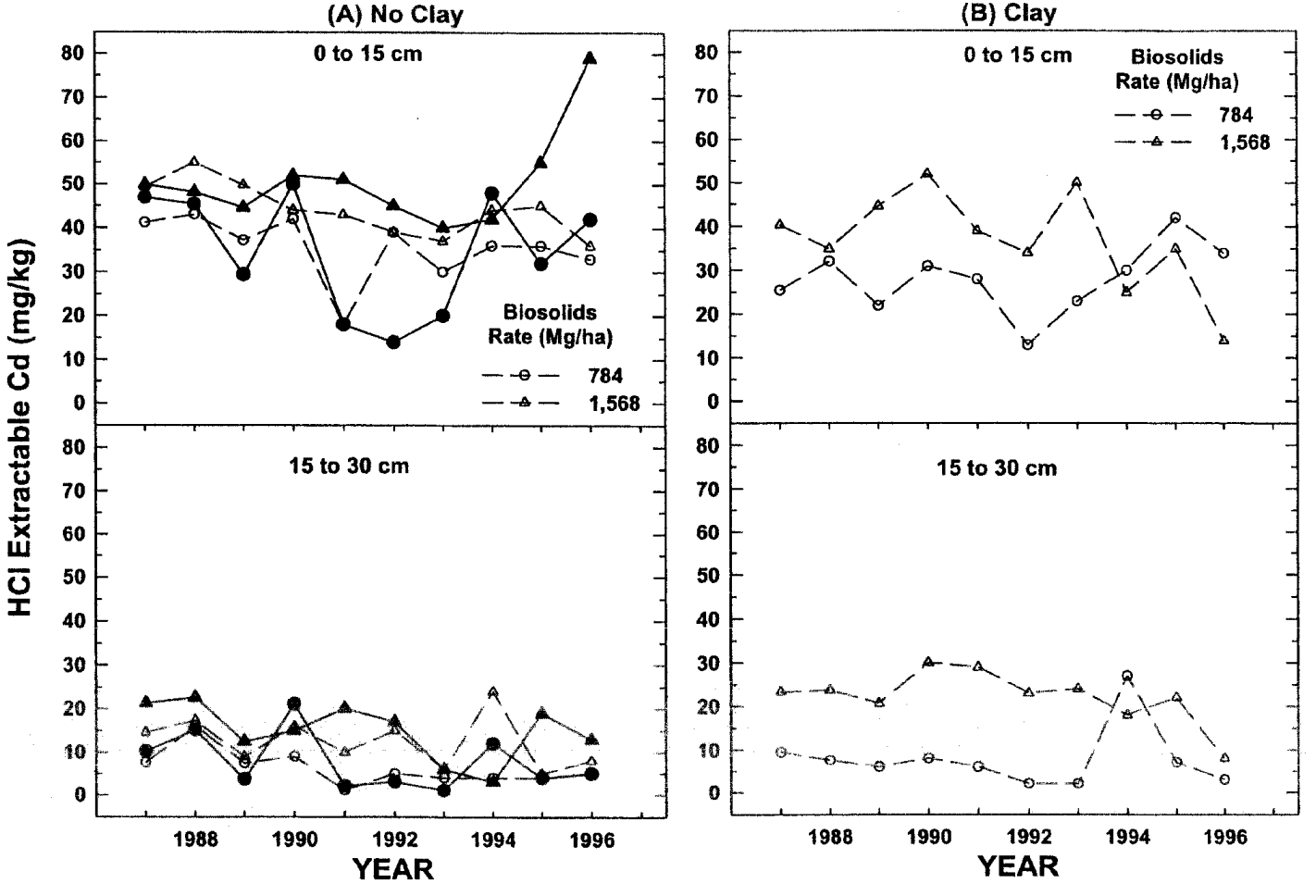
HCl-EXTRACTABLE Cd AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 19

HCl-EXTRACTABLE Cd AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



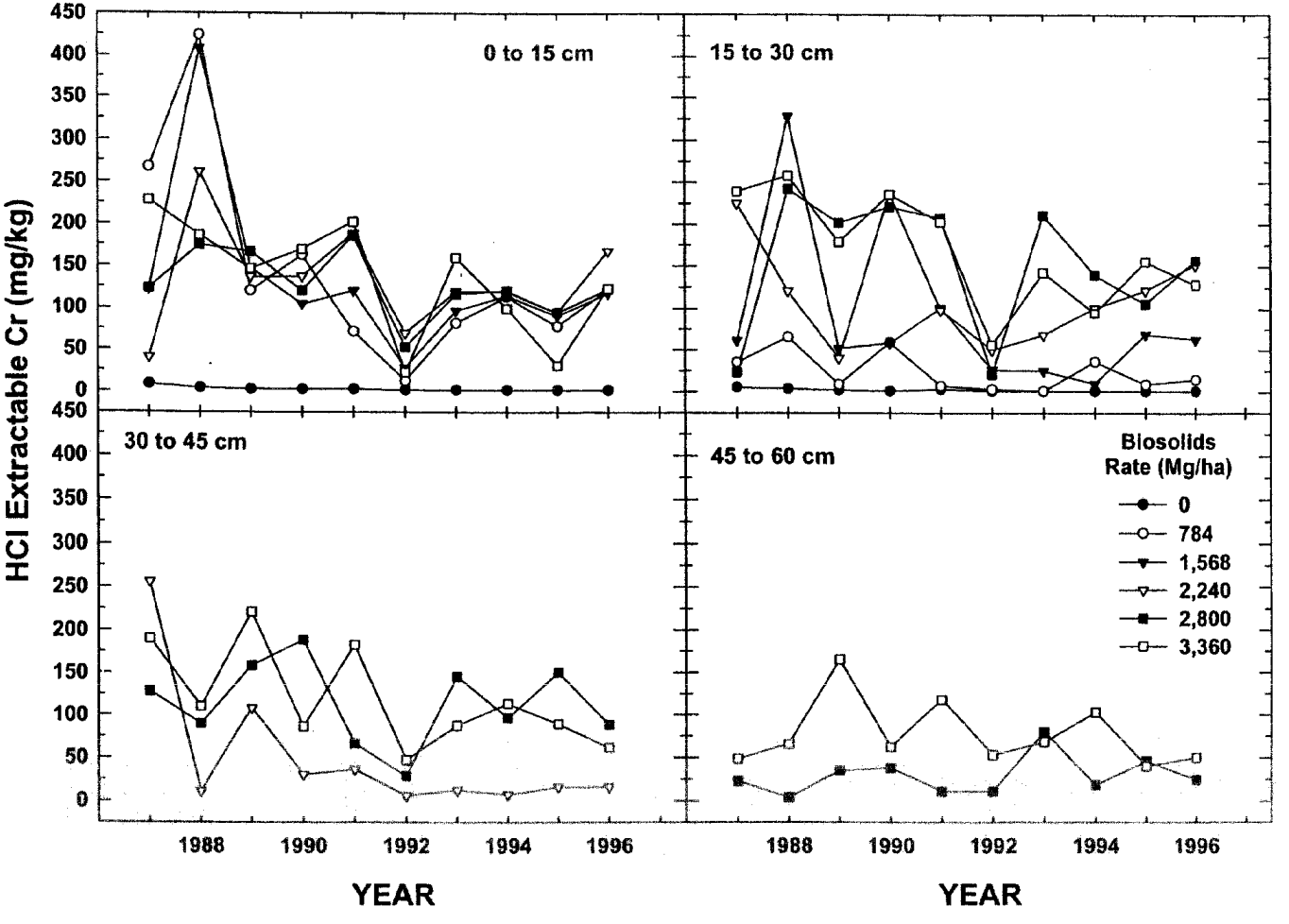
extractable Cd tended to increase with biosolids rate and was higher in the biosolids amended plots than in the unamended plot. The ranges of extractable Cd at the 30- to 45-cm depth of the 2,240 Mg/ha biosolids treatment and at the 45- to 60-cm depth of the 3,360 Mg/ha were similar to the concentrations in the top 30 cm of the unamended plot. Except for higher concentrations of extractable Cd in the 15- to 30-cm depth of the plot amended with 1,568 Mg/ha biosolids and clay (Figure 19B), there were no consistent trend of lime or clay effects on extractable Cd.

HCl-Extractable Chromium. The concentrations of HCl-extractable Cr in the coal refuse are presented in Figures 20 and 21. At the 0- to 15-cm and 15- to 30-cm depths, extractable Cr concentrations were almost always higher in the amended plots than in the unamended plot (Figure 20). In all treatments, extractable Cr concentrations fluctuated during the study, but in the 30- to 45-cm depth, it tended to decrease with time. The concentrations tended to decrease with depth below the 15- to 30-cm depth interval. At the 784 and 1,568 Mg/ha biosolids rates, extractable Cr at the 0- to 15-cm depth of the unlimed plots were higher than in the limed plots

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 20

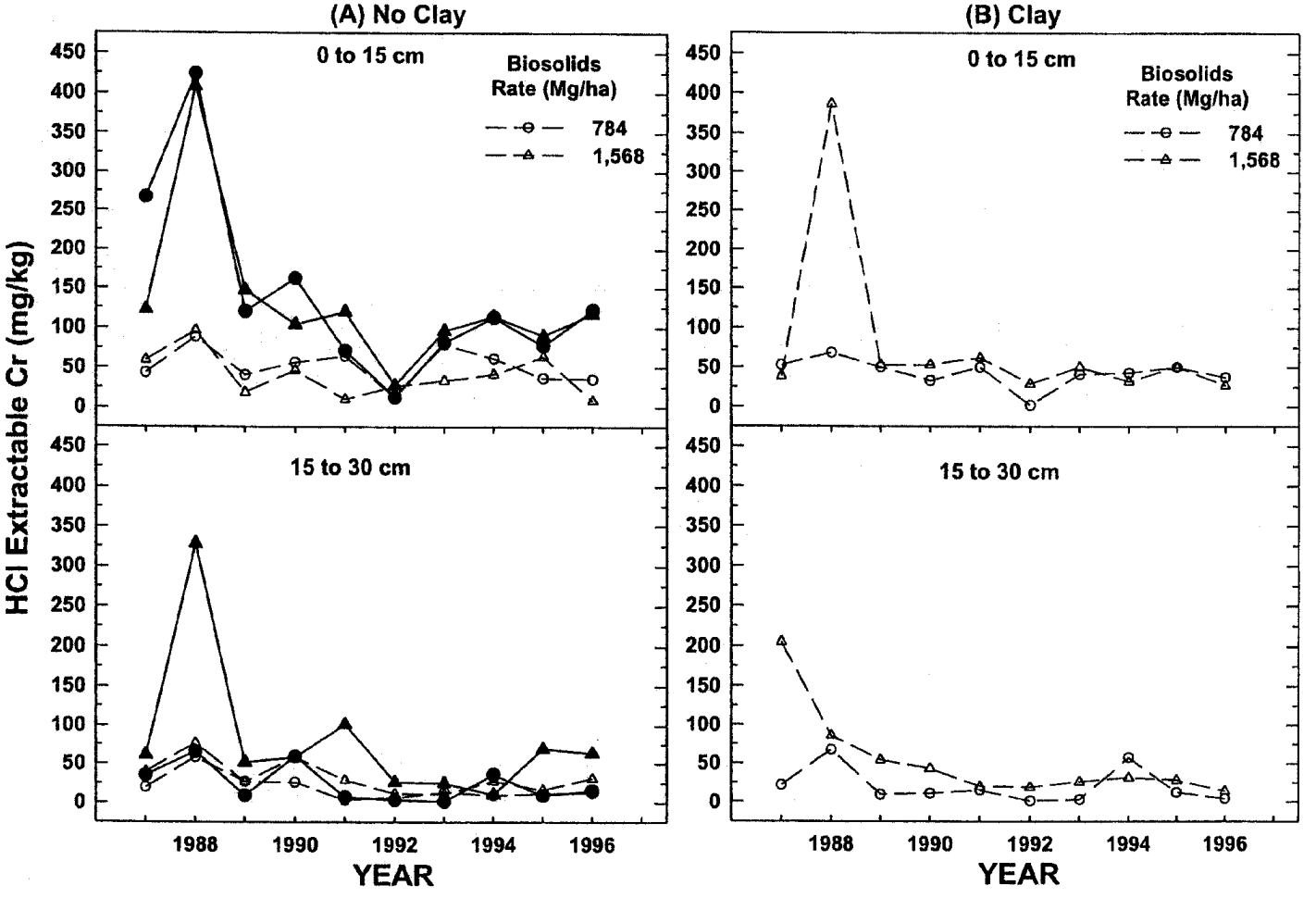
HCl-EXTRACTABLE Cr AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 21

HCl-EXTRACTABLE Cr AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



(Figure 21A). There was no consistent effect of clay on concentrations of extractable Cr (Figure 21B).

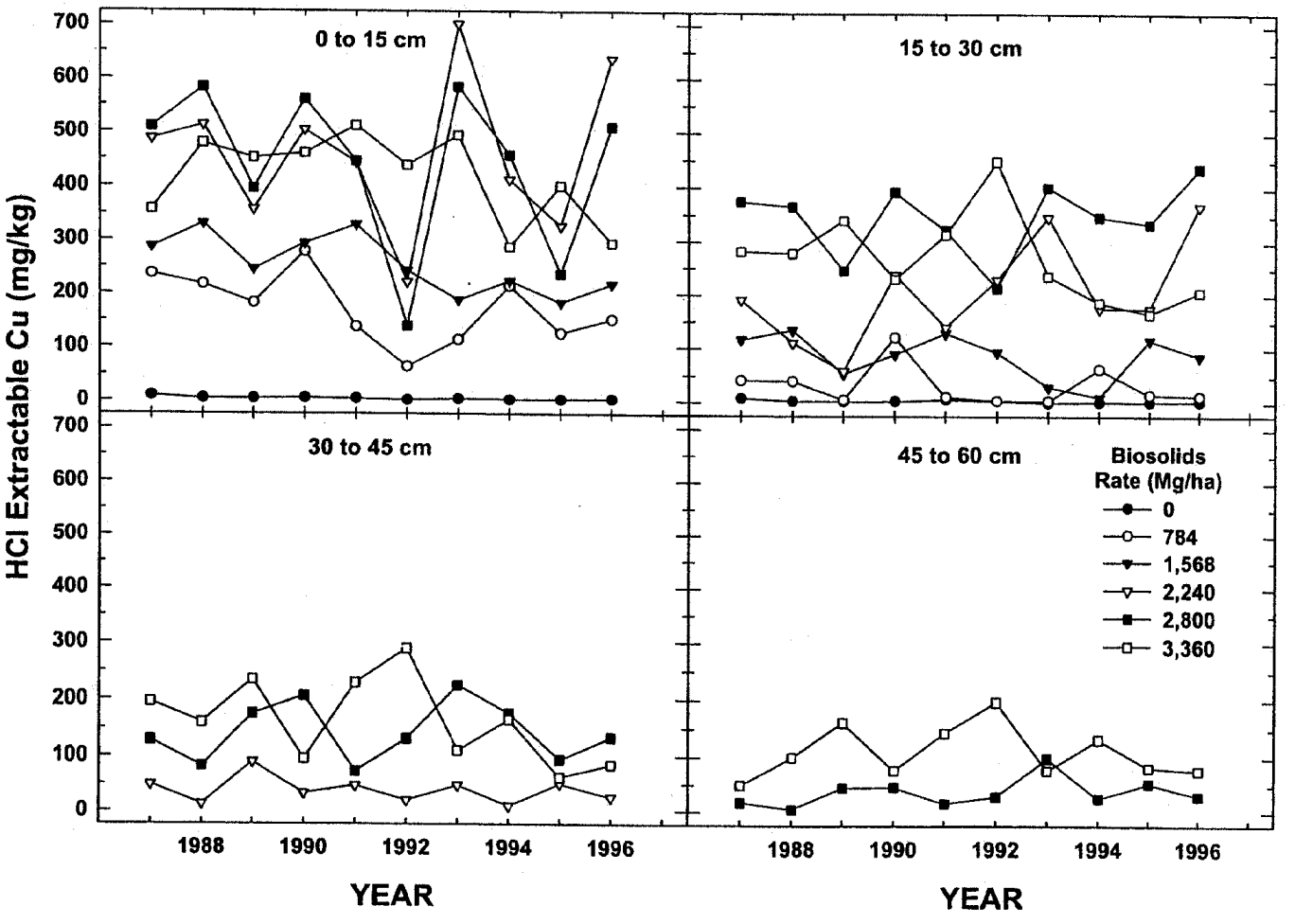
HCl-Extractable Copper. The concentrations of HCl-extractable Cu in the coal refuse are presented in Figures 22 and 23. At the 0- to 15-cm and 15- to 30-cm depths in the unamended plot, extractable Cu concentrations ranged from 1 to 9 mg/kg, and in most years the concentrations were lower than in the amended plots. In all the amended plots, the concentrations of extractable Cu in the coal refuse fluctuated during the study (ranging from 5 to 700 mg/kg) with no defined trend over time. In most years, extractable Cu concentrations tended to decrease with depth in the coal refuse. At the 784 and 1,568 Mg/ha biosolids rates, there was no consistent effect of lime or clay on concentrations of extractable Cu (Figure 23).

HCl-Extractable Nickel. The concentrations of HCl-extractable Ni in the coal refuse are presented in Figures 24 and 25. Extractable Ni concentrations in the coal refuse fluctuated in all the amended plots and generally decreased with depth and time. At the 0- to 15-cm depth, extractable Ni concentrations in all treatments were always higher than in the unamended plot, and in most years, concentrations were

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 22

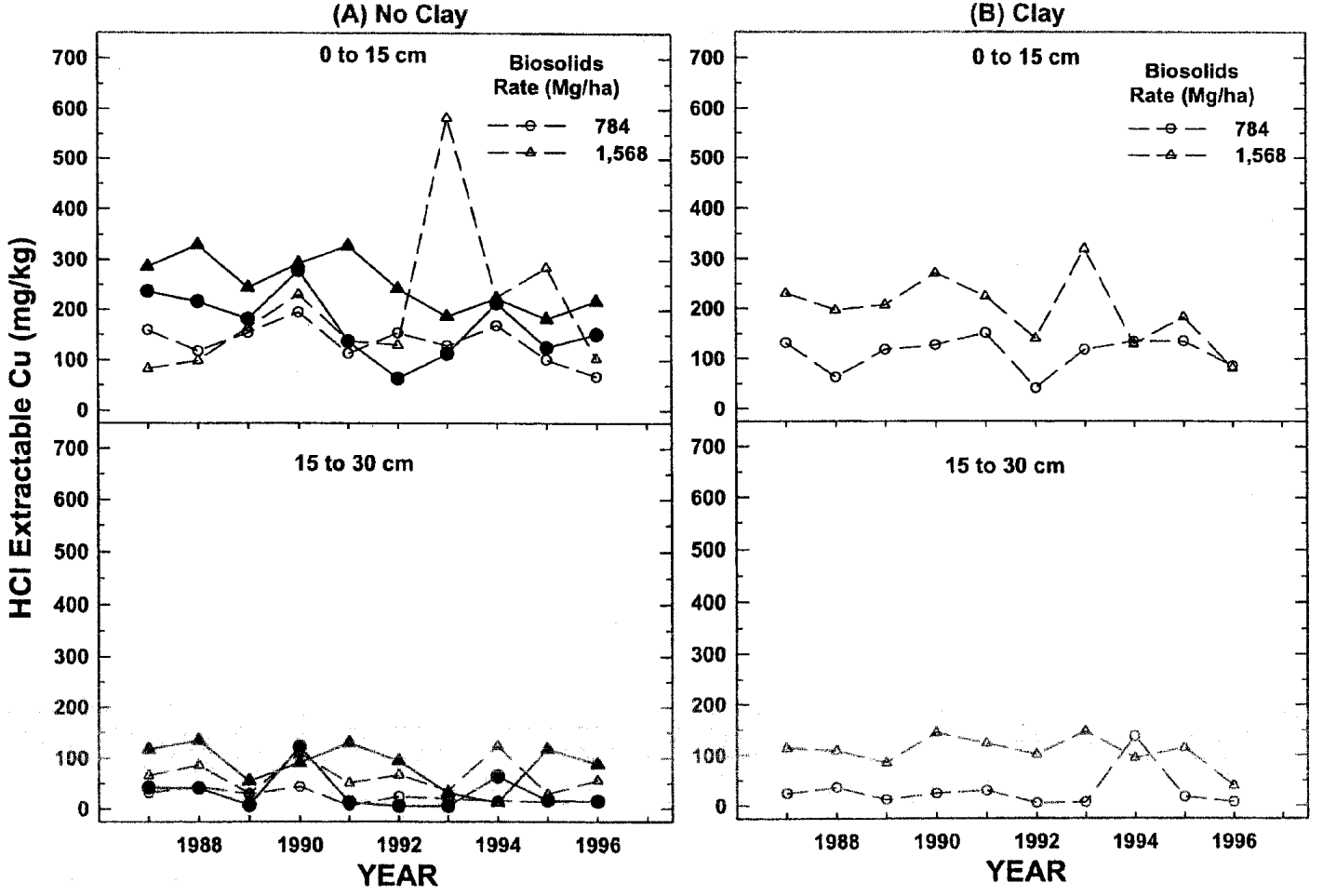
HCl-EXTRACTABLE Cu AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 23

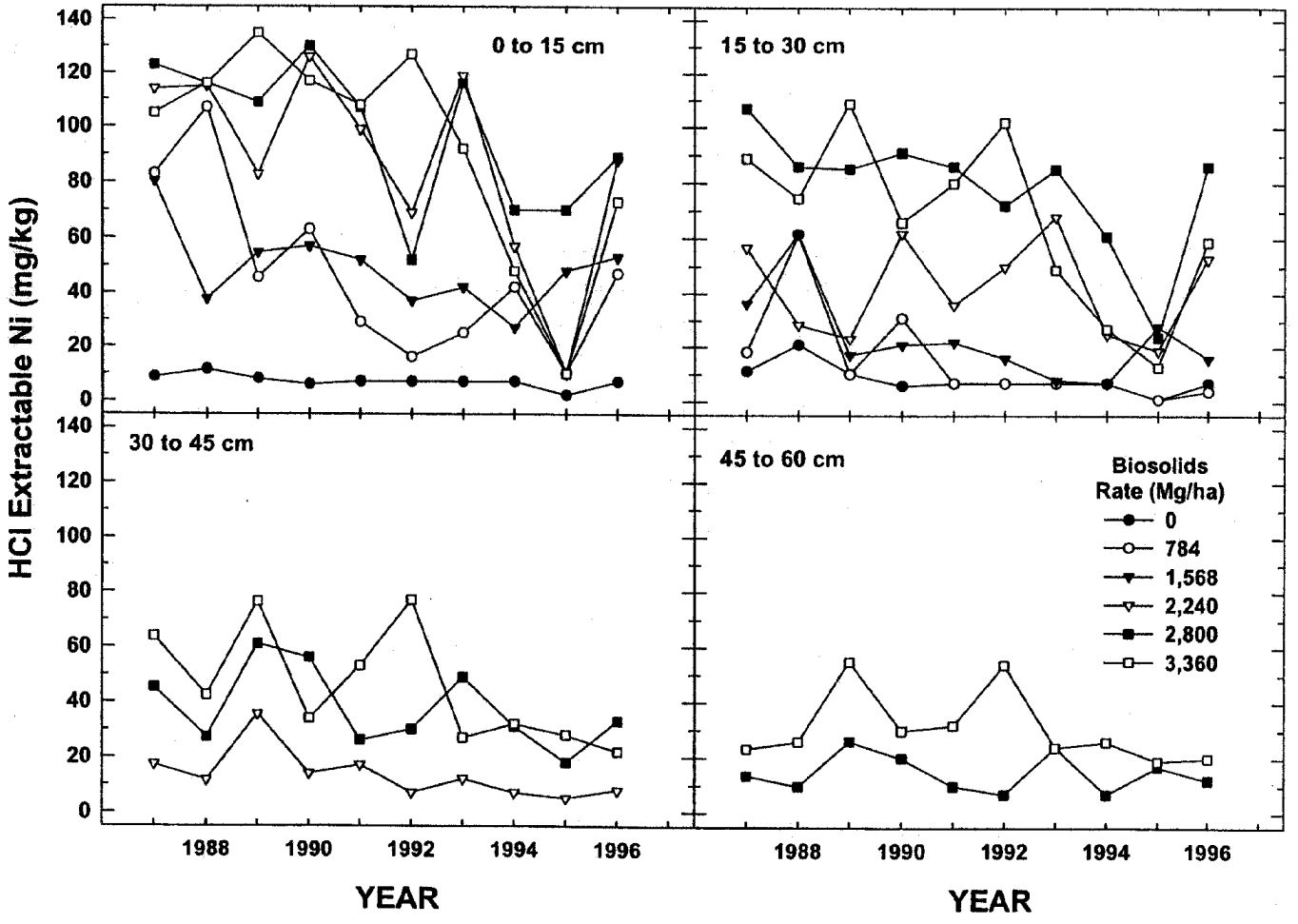
HCl-EXTRACTABLE Cu AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 24

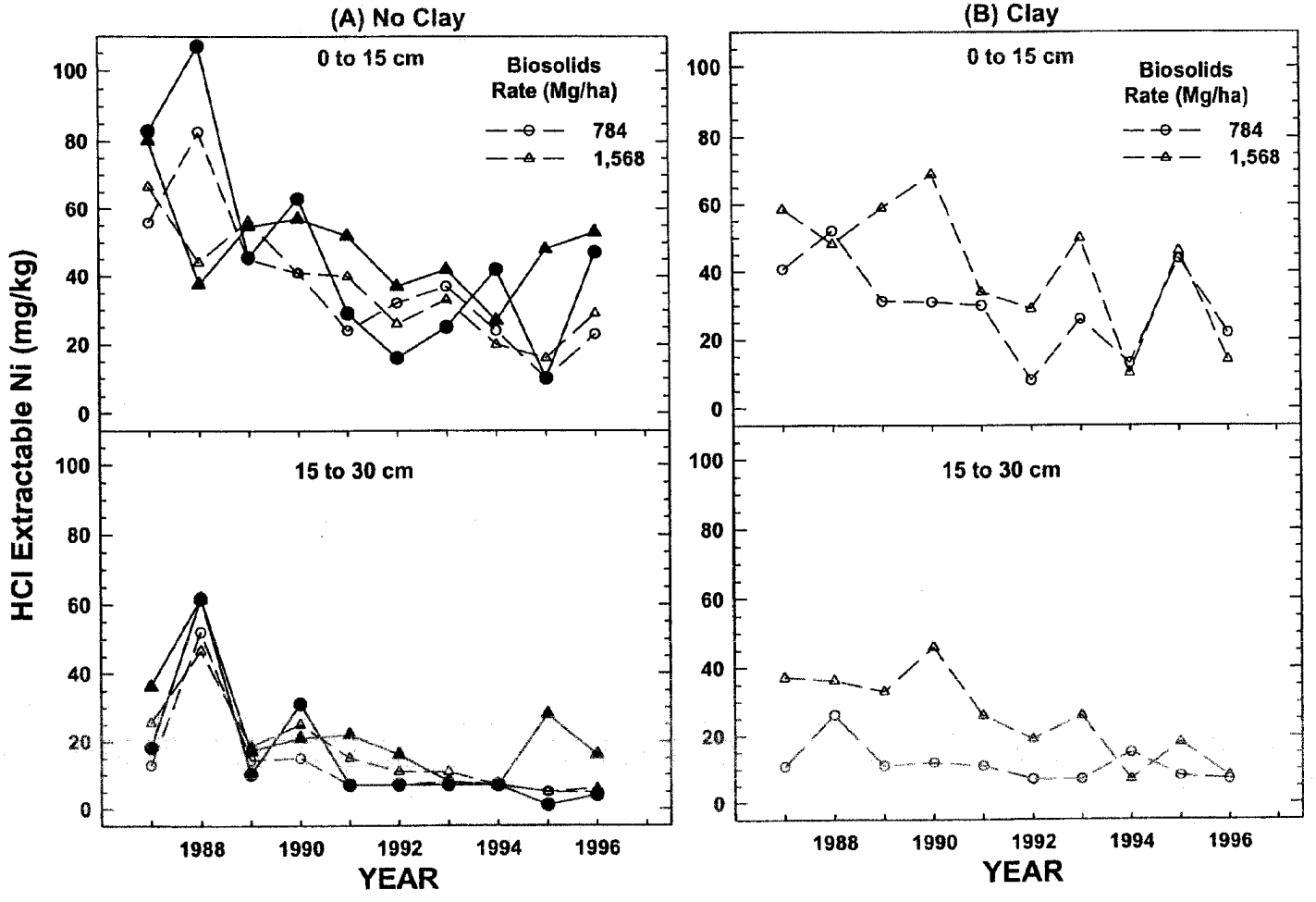
HCl-EXTRACTABLE Ni AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 25

HCl-EXTRACTABLE Ni AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



highest at the three highest biosolids rates (Figure 24). In most years, extractable Ni concentrations at the 30- to 45-cm depth of the 2,240 Mg/ha biosolids rate and at the 45- to 60-cm depth of the 2,800 Mg/ha biosolids rate were similar or slightly higher than in the surface 30 cm of the unamended plot. There were no consistent effects of lime or clay on the concentrations of extractable Ni (Figure 25).

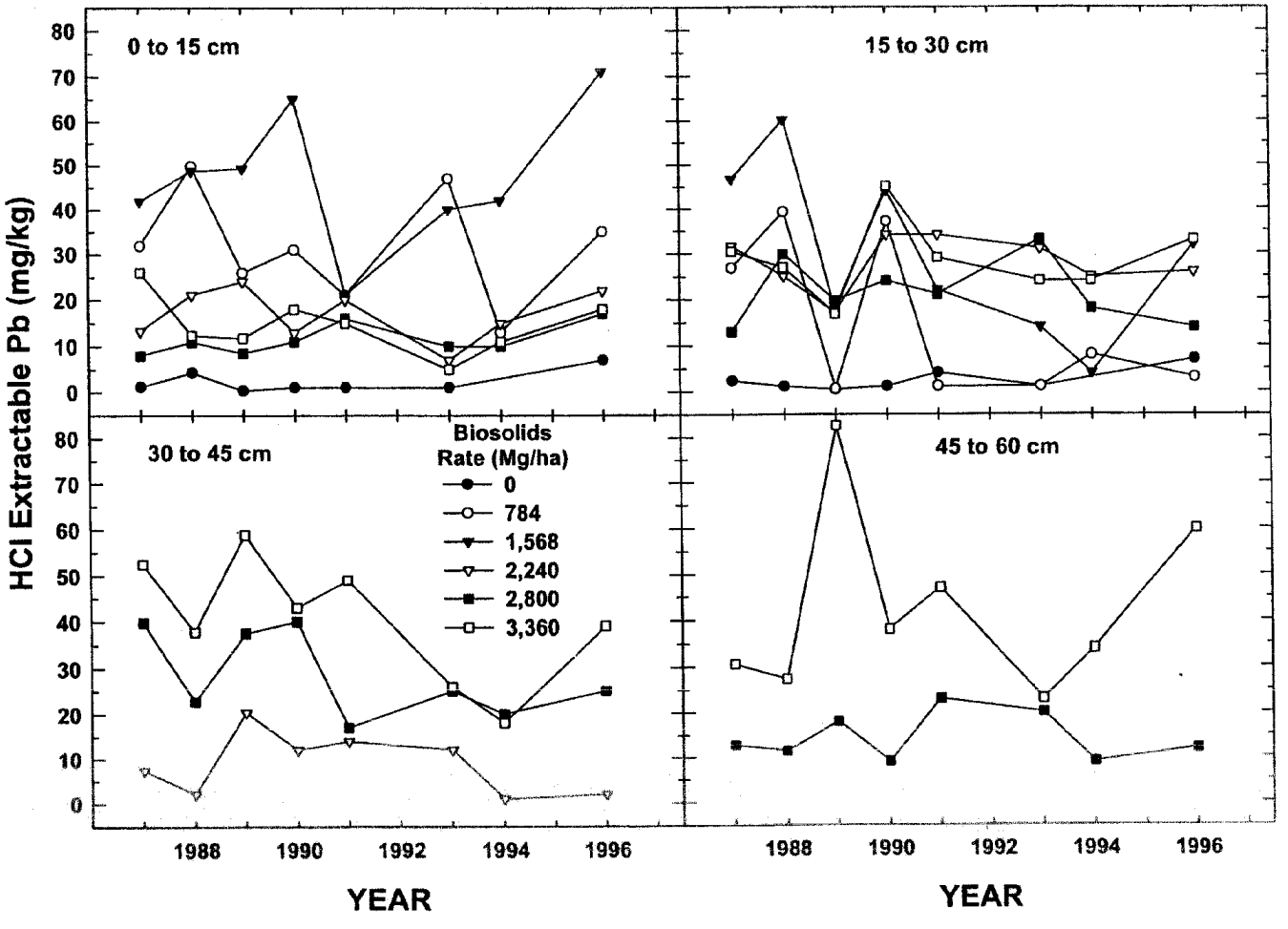
HCl-Extractable Lead. The concentrations of HCl-extractable Pb in the coal refuse are presented in Figures 26 and 27. At the 0- to 15-cm and 15- to 30-cm depths in the unamended plot, the extractable Pb concentrations ranged from 0 to 7 mg/kg, and in most years the concentrations were lower than in the amended plots. In most years, extractable Pb in the 30- to 45-cm and 45- to 60-cm depths, increased with biosolids rate. At the 784 and 1,568 Mg/ha biosolids rates, except for the higher concentrations in the 0- to 15-cm depth of the plots amended with clay, there were no consistent differences between the extractable Pb concentrations of the limed and unlimed plots (Figure 27A) and the plots with and without clay (Figure 27B).

HCl-Extractable Zinc. The concentrations of HCl-extractable Zn in the coal refuse are presented in Figures 28

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 26

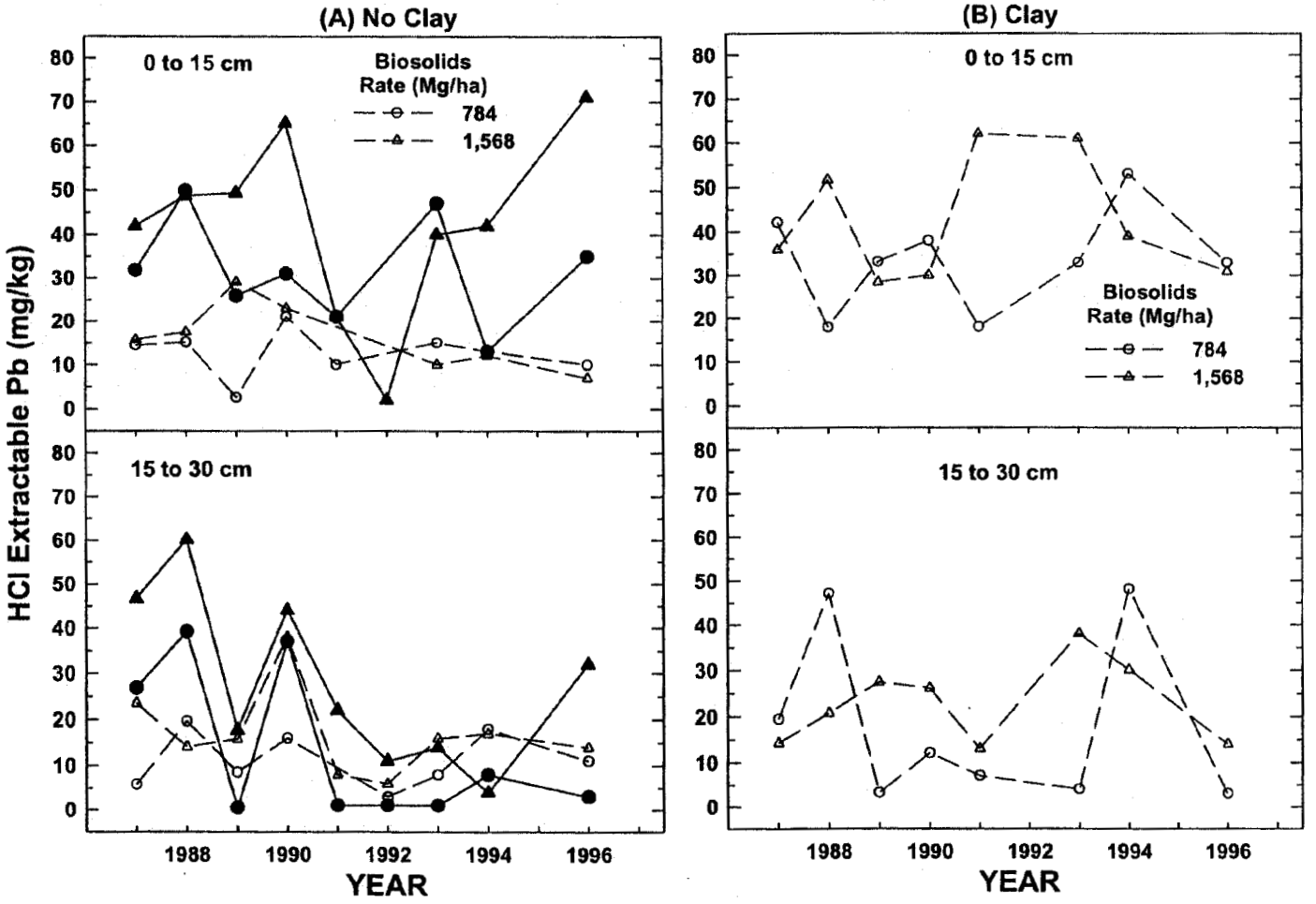
HCl-EXTRACTABLE Pb AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 27

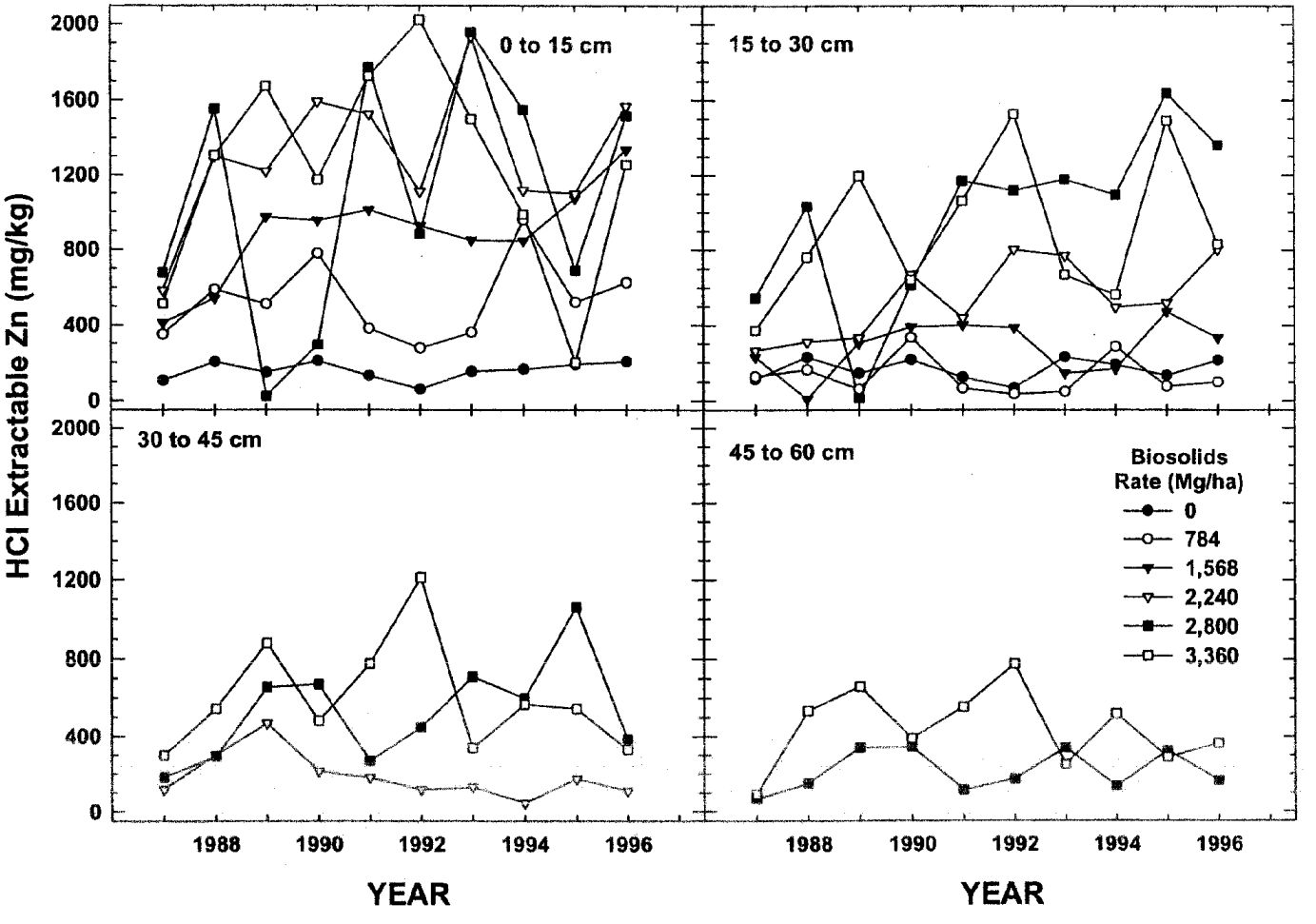
HCl-EXTRACTABLE Pb AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 28

HCl-EXTRACTABLE Zn AT FOUR DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY



and 29. In most years, extractable Zn concentrations in most of the amended plots were higher than in the unamended plot, ranging from nondetectable to approximately 2,000 mg/kg, especially in the 0- to 15-cm depth. Extractable Zn tended to decrease with depth in the coal refuse. In most years, extractable Zn at the 0- to 15-cm depth increased with biosolids rate. There were no consistent effects of biosolids rate on Zn concentrations at the lower depths. At the 784 Mg/ha biosolids rate, Zn concentrations in most years at the 0- to 15-cm and 15- to 30-cm depths were higher in the limed plots than in the unlimed plots (Figure 29A). At the 1,568 Mg/ha biosolids rate, Zn concentrations at the 0- to 15-cm depth were higher in the unlimed plot than in the limed plot in most years (Figure 29A). There were no consistent effects of clay on the concentrations of extractable Zn (Figure 29B).

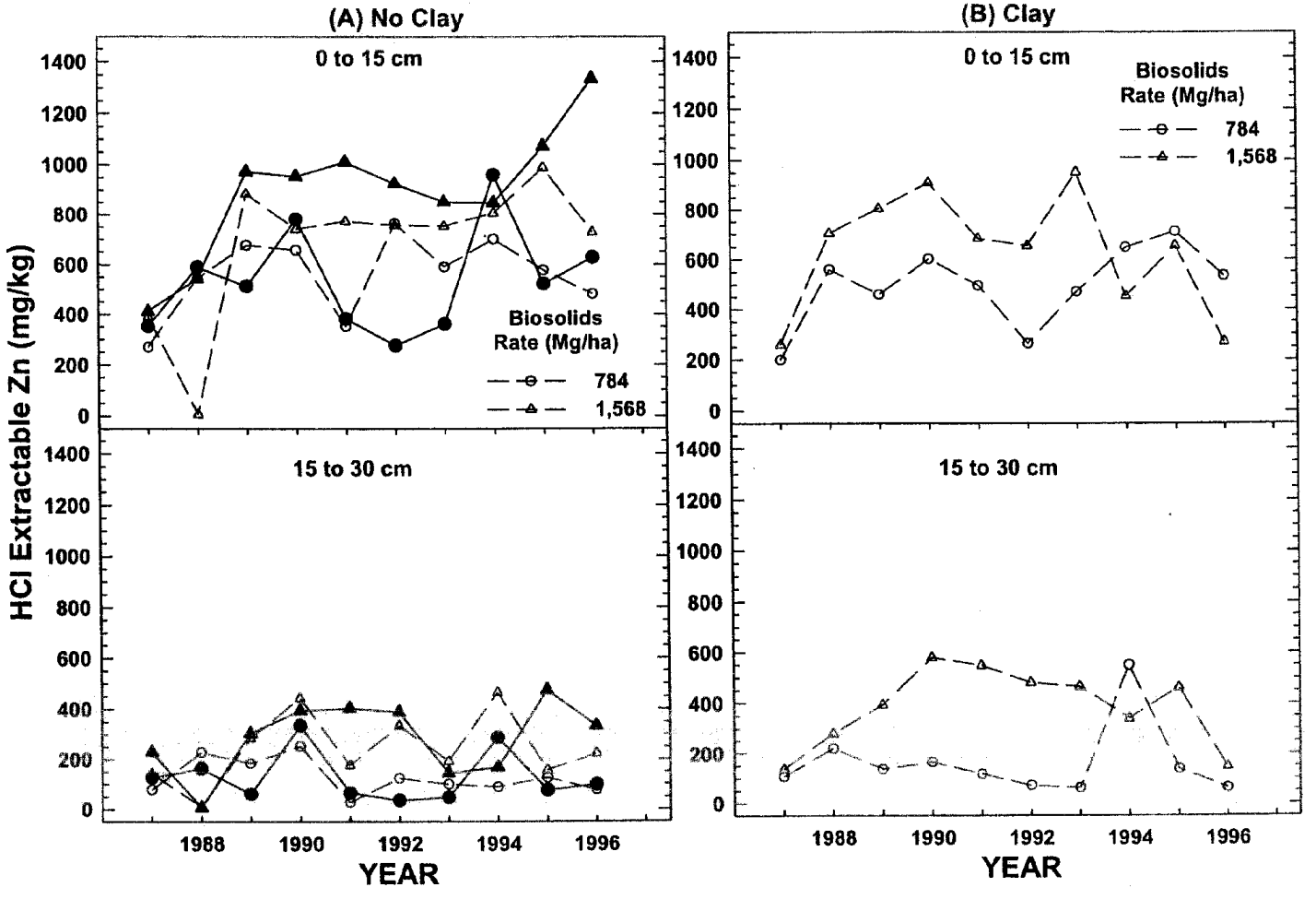
Vegetative Cover and Forage Yield

Establishment of vegetative cover on the coal refuse is essential to stabilize the surface, minimize wind and water erosion, reduce leaching of constituents, and immobilize constituents in the vegetative tissue. Vegetative yield was measured only for the first and second growing seasons, 1988 and 1989. The two-year period was very droughty, but

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 29

HCl-EXTRACTABLE Zn AT TWO DEPTHS IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (CLOSED SYMBOLS) AND BIOSOLIDS + LIME (OPEN SYMBOLS) WITHOUT (A) AND WITH (B) CLAY



vegetative cover in the amended plots was adequate. Throughout the study, the unamended plot was bare.

The mean forage yield for 1988 and 1989 are presented in Table 7. For the limed plots, the data were summarized as means for the plots with and without clay. There was no marked difference between the forage yields in the amended plots. Forage yields were usually highest on the flatter upper and lower slopes and lowest on the steeper middle slopes. The lack of vegetative growth on the unamended plot is most likely due to factors such as the acidic conditions (Figures 4 and 5) and the high EC (Figure 16).

Concentration of Sodium in Forage

A summary of the concentrations of Na in the forage tissue is presented in Table 8. For the limed plots, the data were summarized as the means of the plots with and without clay. The Na concentrations ranged from nondetectable to 51 mg/kg, and there were no consistent trends related to effects of biosolids or lime application rates. The forage Na concentrations observed are relatively low compared to the normal range found in plant tissue (Lunt, 1966) and coincides with the low extractable Na levels in the amended coal refuse.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 7

MEAN FORAGE YIELDS ON COAL REFUSE DURING THE FIRST TWO YEARS AFTER AMENDMENT WITH BIOSOLIDS ONLY AND BIOSOLIDS + LIME

Application Rate		Slope Position	Year	
Biosolids	Lime	Sampled	1988	1989
-------Mg/ha-------			Yield ----Mg/ha-----	
0	0	Upper	0.00	0.00
		Middle	0.00	0.00
		Lower	0.00	0.00
784	0	Upper	1.83	2.04
		Middle	0.10	0.70
		Lower	2.32	2.27
1,568	0	Upper	2.47	1.39
		Middle	0.31	0.95
		Lower	2.09	1.35
2,240	0	Upper	2.44	1.17
		Middle	1.72	1.24
		Lower	2.31	1.08
2,800	0	Upper	1.39	1.32
		Middle	1.06	1.18
		Lower	1.35	1.26
3,360	0	Upper	1.48	1.15
		Middle	0.45	0.73
		Lower	1.38	0.00
784	179	Upper	1.93	1.16
		Middle	0.89	0.99
		Lower	2.34	0.95
1,568	179	Upper	1.72	1.37
		Middle	0.79	1.24
		Lower	2.33	1.31

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 8

SUMMARY OF Na CONCENTRATIONS IN FORAGE GROWN IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY AND BIOSOLIDS + LIME

Biosolids	Lime[1]	Na Concentration		
		Minimum	Maximum	Mean
------ Mg/ha -------		---------- mg/kg ----------		
784	0	10	43	27
1,568	0	5.0	28	13
2,240	0	6.5	51	24
2,800	0	7.0	50	24
3,360	0	<0.2	46	17
784	179	7.3	32	16
1,568	179	7.0	19	12

[1]Data for the limed treatments are the mean for plots amended with and without clay.

Excessive concentrations of Na in the soil can reduce the performance of vegetation primarily by its negative impacts on soil physical properties, and to a lesser extent by affecting plant nutrient balance. The ESP, which is a measure of the concentration of Na relative to the soil cation exchange capacity, is more important than absolute soil Na concentrations for assessing the potential for impact on plants. The ESP in the amended coal refuse ranged from 0.1 to 2.5 (Tables 5 and 6). At these ESP levels, there is minimal potential for adverse impacts on soil physical properties and the physiology and performance of the crop.

There is very little documentation in the literature on the relationship between Na accumulation in plant tissue and the effects on plant performance. Lunt (1966) reported that in soil with ESP ranging from 2-5, the concentrations of Na ranged from 920 to 1,610 in barley (*Hordeum vulgare*) and less than 230 mg/kg in clover (*Trifolium spp.*). It was indicated that at these concentrations Na will have no significant impact on plant performance.

Concentration of Metals in Forage

Forage samples from the lower, middle, and upper slope of the coal refuse pile were collected and analyzed separately.

There were no consistent differences between concentrations of metals in samples collected from the three locations. Therefore, these data were combined as the mean for each plot. No forage tissue was available from the unamended plot.

FORAGE CADMIUM

The concentrations of Cd in the forage tissue are presented in Figure 30. Cadmium concentrations fluctuated during the study and the highest level of about 8 mg/kg was observed at the 784 Mg/ha biosolids rate. Except in 1990 where Cd concentrations in some treatments increased above the 1988 values, the concentration of Cd in most of the treatments tended to decrease with time, and by the end of the study the concentrations ranged from 2 to 6 mg/kg. At the 784 and 1,568 Mg/ha biosolids rates, there was no apparent effect of the lime treatment but forage Cd concentrations were usually lower in the plots with clay than in the plots without clay (Figure 30B).

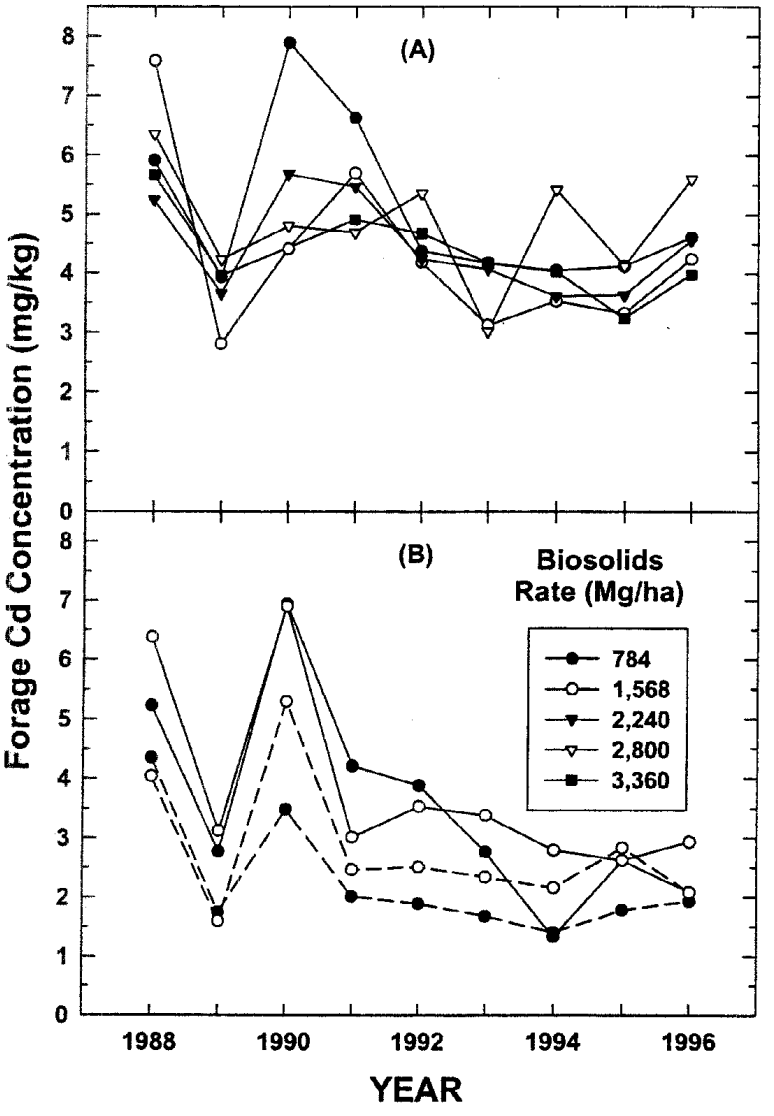
FORAGE CHROMIUM

The concentrations of Cr in the forage tissue are presented in Figure 31. In 1988, concentrations ranged from approximately 10 to 22 mg/kg and tended to decrease as biosolids rate increased. After 1988, Cr concentrations decreased

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 30

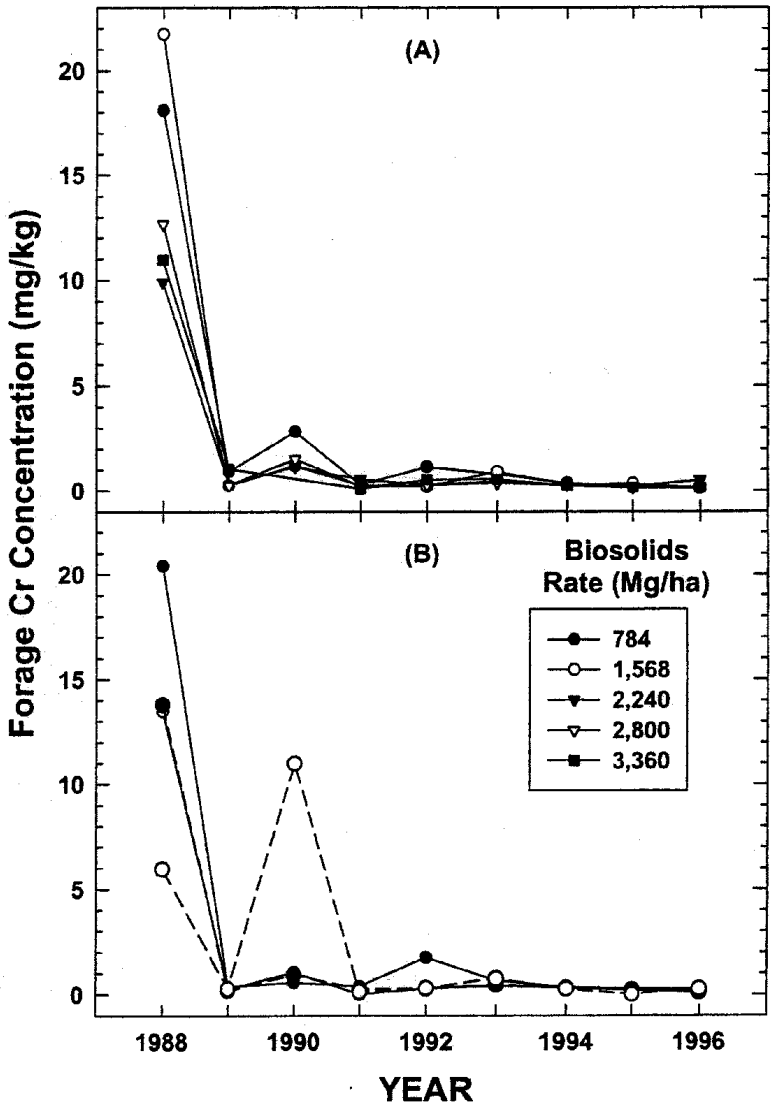
CONCENTRATIONS OF Cd IN FORAGE GROWN IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 31

CONCENTRATIONS OF Cr IN FORAGE GROWN IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



sharply, ranging from nearly non-detectable levels to about 2.5 mg/kg (except for slightly higher concentrations in 1990) and remained at these levels for the remainder of the study with no consistent differences between the treatments. At the 784 and 1,568 Mg/ha biosolids rates, there was very little difference between the unlimed (Figure 31A) and limed (Figure 31B) plots. There was very little difference between the plots amended with and without clay (Figure 31B). The exceptions to this were in 1988 where concentrations were lower in the clay-amended plots, and in 1990 where the concentrations at the 1,568 Mg/ha biosolids rate were highest in the clay amended plot.

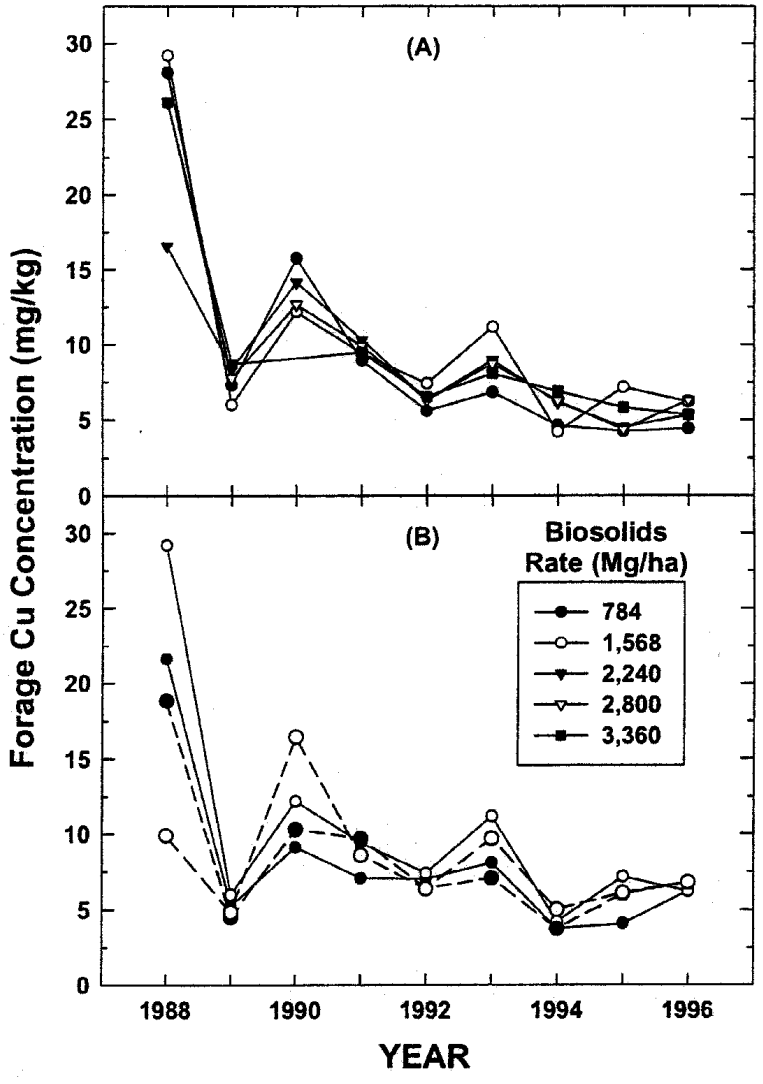
FORAGE COPPER

The concentrations of Cu in the forage tissue are presented in Figure 32. In 1988, the forage Cu concentrations ranged from 13 to 29 mg/kg. After then, the concentrations decreased sharply in 1989, increased in 1990, and then decreased gradually during the remainder of the study to levels ranging from 4.5 to 5.5 mg/kg. At the 784 and 1,568 Mg/ha biosolids rates, there was no noteworthy difference in forage Cu between the unlimed plots (Figure 32A) and the limed plots (Figure 32B). The trend in forage Cu was similar between the

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 32

CONCENTRATIONS OF Cu IN FORAGE GROWN IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



plots amended with and without clay (Figure 32B), except in 1988 where Cu concentration was highest in the plots receiving no clay.

FORAGE NICKEL

The concentrations of Ni in the forage tissue are presented in Figure 33. In 1988, the forage Ni concentrations ranged from 8 to 18 mg/kg and there was no apparent effect of biosolids application rate. Except for increased Ni levels in some treatments during the period of 1989 to 1991, Ni concentrations decreased with time after 1988, and ranged from 1.5 to 5.5 mg/kg by the end of the study. In most years, forage Ni concentrations at the 784 and 1,568 Mg/ha biosolids rates tended to be higher in the unlimed plots (Figure 33A) than in the limed plots (Figure 33B). There were no consistent differences between the plots amended with and without clay (Figure 33B).

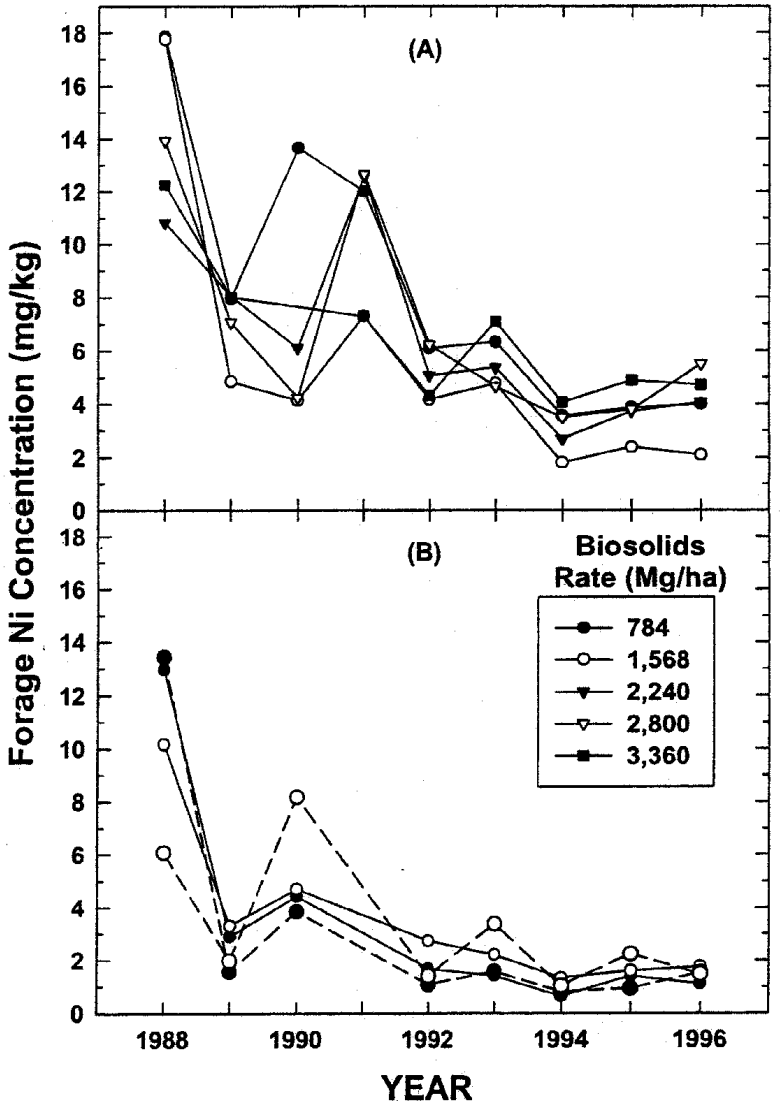
FORAGE LEAD

The concentrations of Pb in the forage tissue are presented in Figure 34. In all the plots, the forage Pb concentrations were highest in 1988, ranging from 4.6 to 9.2 mg/kg. After then, the concentrations decreased sharply, and in most plots they remained below 1 mg/kg for the remainder of the

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 33

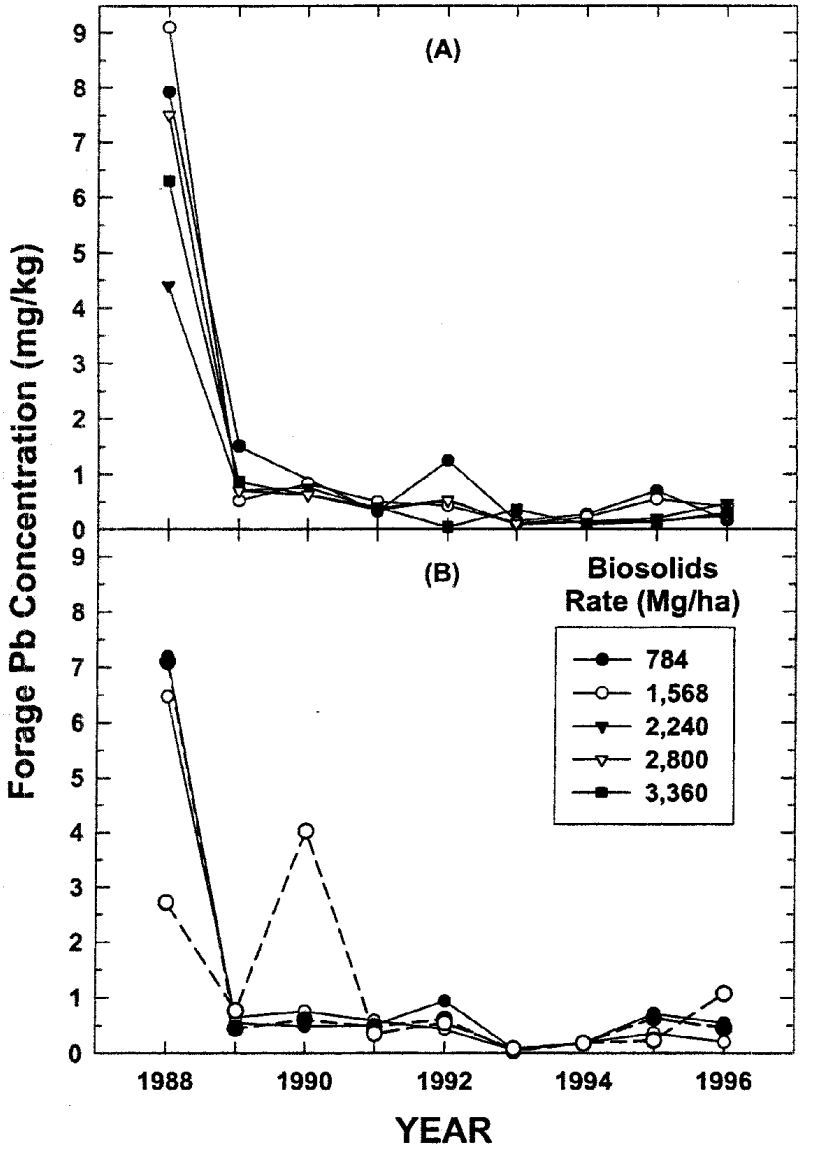
CONCENTRATIONS OF Ni IN FORAGE GROWN IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 34

CONCENTRATIONS OF Pb IN FORAGE GROWN IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



study. There was no consistent trend related to biosolids loading rate on forage Pb concentrations. At the 784 and 1,568 Mg/ha biosolids rates, forage Pb concentrations in 1988 were higher in the unlimed plots (Figure 34A) than in the limed plots (Figure 34B). Then, there were no consistent effects from lime during the remainder of the study. The concentrations of Pb in the plots treated with and without clay were similar, except in 1988 and 1990 at the 1,568 Mg/ha biosolids rate where the Pb concentrations were higher in the clay-treated plot (Figure 34B).

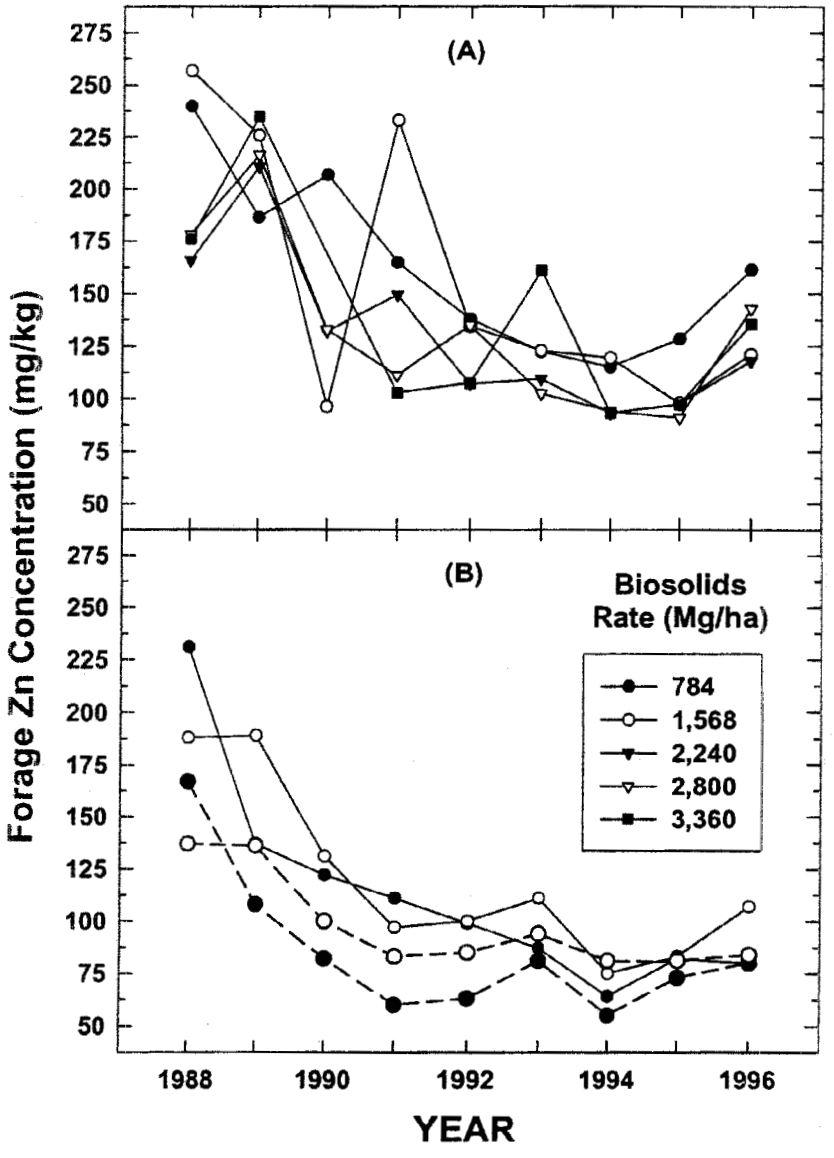
FORAGE ZINC

The concentrations of Zn in the forage tissue are presented in Figure 35. Except for a few fluctuations, forage Zn concentrations decreased gradually with time after 1988, and the lowest concentrations were observed mostly in 1994 and 1995. In 1996, the forage Zn concentrations tended to increase, ranging from 76 to 160 mg/kg. In the unlimed plots, there was no consistent effect of biosolids application rate on the forage Zn concentrations (Figure 35A). Except in 1988, forage Zn concentrations in the plots amended with 179 Mg/ha lime tended to be higher at 1,568 Mg/ha than at the 784 Mg/ha biosolids rate. In most years, forage Zn concentrations at

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 35

CONCENTRATIONS OF Zn IN FORAGE GROWN IN COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



the 784 and 1,568 Mg/ha biosolids rate were higher in the unlimed plots (Figure 35A) than in the limed plots and higher in the plots having no clay than in the plots amended with clay (Figure 35B).

COMPARISON OF METAL UPTAKE IN FORAGE TISSUE WITH USEPA PART 503 BIOSOLIDS RISK ASSESSMENT MODEL

The mass of metal applied through biosolids application and the concentrations of metal in the forage tissue were used to determine metal uptake coefficients (UC) according to the approach used in the USEPA Part 503 risk assessment model. In this approach, the UC is derived as the slope of the linear regression model of soil metal loading (kg metal/ha) vs. metal concentration in the plant tissue (mg metal/kg tissue). The UC values were used in the Part 503 risk assessment model to predict the increase in plant tissue metal concentration that results from plant uptake of metals from biosolids application.

The Part 503 risk assessment Pathway 6 is intended to protect animals that ingest plants (forage and grain) grown on biosolids-amended soil. This pathway evaluates the metal transfer path:

Biosolids → Soil → Plant → Animal

In this study, the soil metal loadings for the nine treatments (n = 9) were regressed against the forage tissue metal concentrations in each year, and the UC values were estimated as the slopes of the regression equations. The UC values derived were compared to the UC values used the Part 503 risk assessment Pathway 6.

A summary of the UC values obtained by regression analysis of the data in each year for the six metals evaluated in the forage grown on the amended coal refuse are presented in Table 9. The UC values used for Pathway 6 of the USEPA Part 503 risk assessment are also presented for comparison. In most years, the correlation coefficient (r) of the regression was not statistically significant at the 5 percent probability level ($r < 0.67$, $n = 9$). The data in Table 9 show that the response of metal concentrations in forage to biosolids metal loading ranged from negative to positive, resulting in UC values ranging from negative to positive. All the maximum UC values computed were much lower than UC values predicted in the Part 503 risk assessment model.

Chemical Characteristics of Surface Water Runoff

Surface water runoff was sampled quarterly every year from collection devices that were installed in the middle of

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 9

METAL UPTAKE COEFFICIENTS (UC)[1] FOR FORAGE GROWN ON COAL REFUSE AMENDED WITH BIOSOLIDS ONLY AND BIOSOLIDS + LIME

Metal	Minimum	Maximum	Mean	Part 503[2]
Cd	-0.007	0.013	0.006	0.070
Cr	-0.003	0.000	0.000	ND[3]
Cu	0.000	0.002	0.001	0.012
Ni	-0.009	0.011	0.006	0.055
Pb	-0.003	0.000	-0.001	0.002
Zn	-0.011	0.025	0.006	0.048

[1]UC = slope of the regression metal concentration in forage tissue (mg/kg) vs. biosolids metal loading (kg/ha).
[2]Uptake coefficients used for Agricultural Pathway 6 of the USEPA Part 503 Risk Assessment.
[3]ND = No data.

the lower slope in each treatment. In some sampling periods, sample volumes were insufficient to conduct analyses.

SURFACE WATER pH AND ACIDITY

The pH of surface water runoff is presented in Figure 36. The pH of surface runoff from the unamended plot was relatively constant during the study, ranging from pH 2.3 to 3.0. Except in the plot amended with 784 Mg/ha biosolids only, where surface runoff pH fluctuated between pH 3.5 and 6.4, the effectiveness of all the amendments in controlling the pH of surface runoff was similar, fluctuating between pH 6.2 to 7.8.

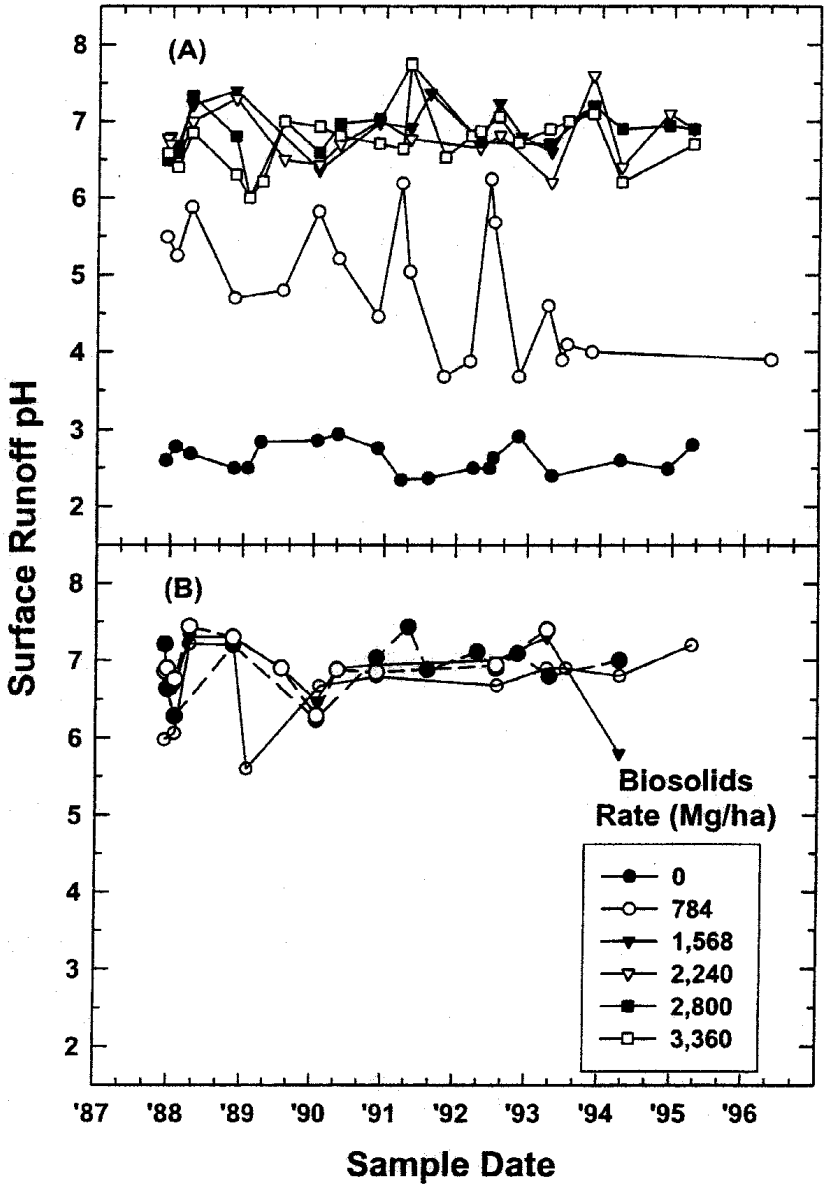
The surface water runoff acidity is presented in Figure 37. In the unamended plot, surface runoff acidity was usually much higher than in the amended plots, and it fluctuated widely during the study, ranging from approximately 10 to 8,500 mg/L (Insert, Figure 37). Except in the unlimed plot of the 784 Mg/ha biosolids application rate, where the acidity fluctuated to levels up to 460 mg/L, the acidity in the amended plots was usually less than 25 mg/L during the study. There was no consistent effect of the clay amendment on surface runoff acidity (Figure 37B).

The surface water runoff alkalinity is presented in Figure 38. There was no measurable alkalinity in the unamended

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 36

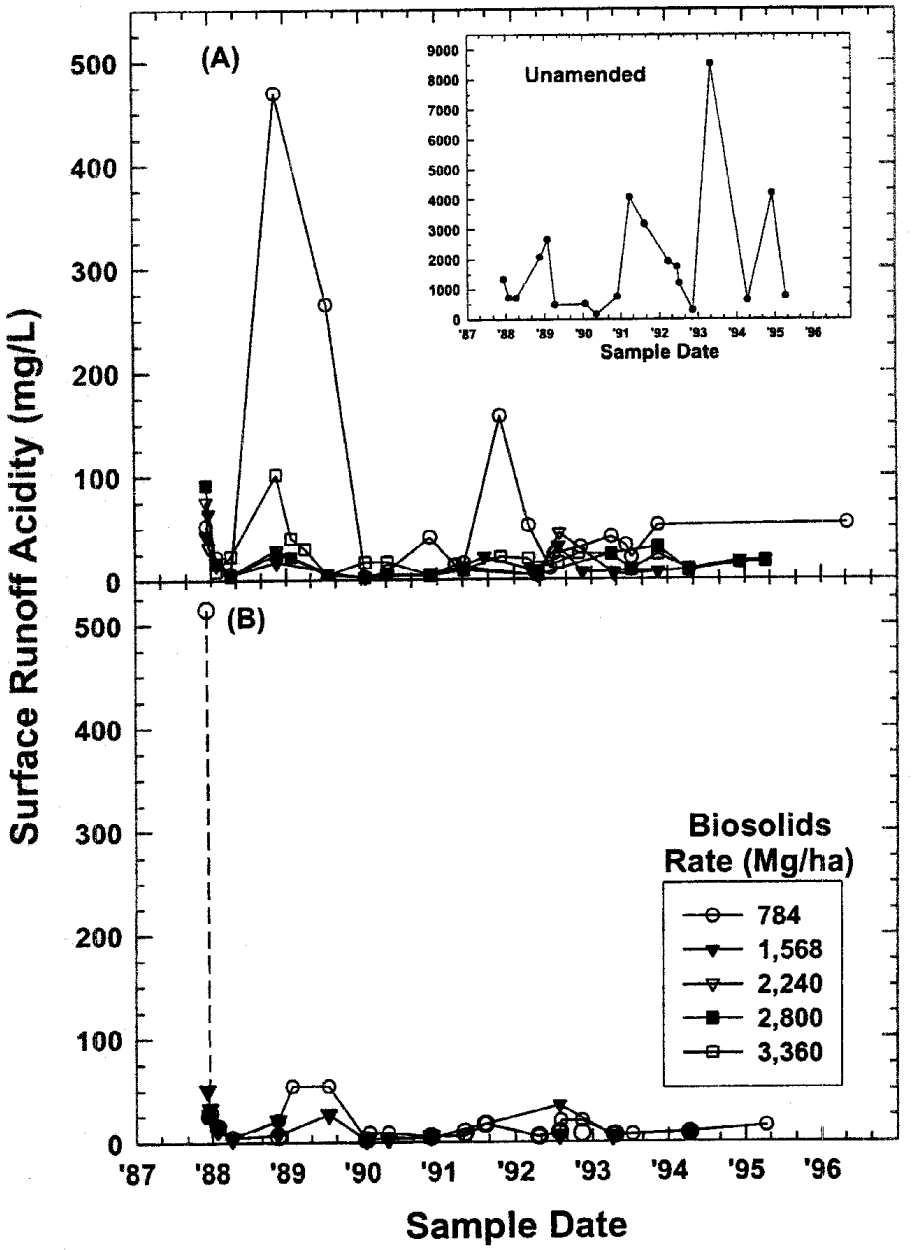
pH OF SURFACE WATER RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 37

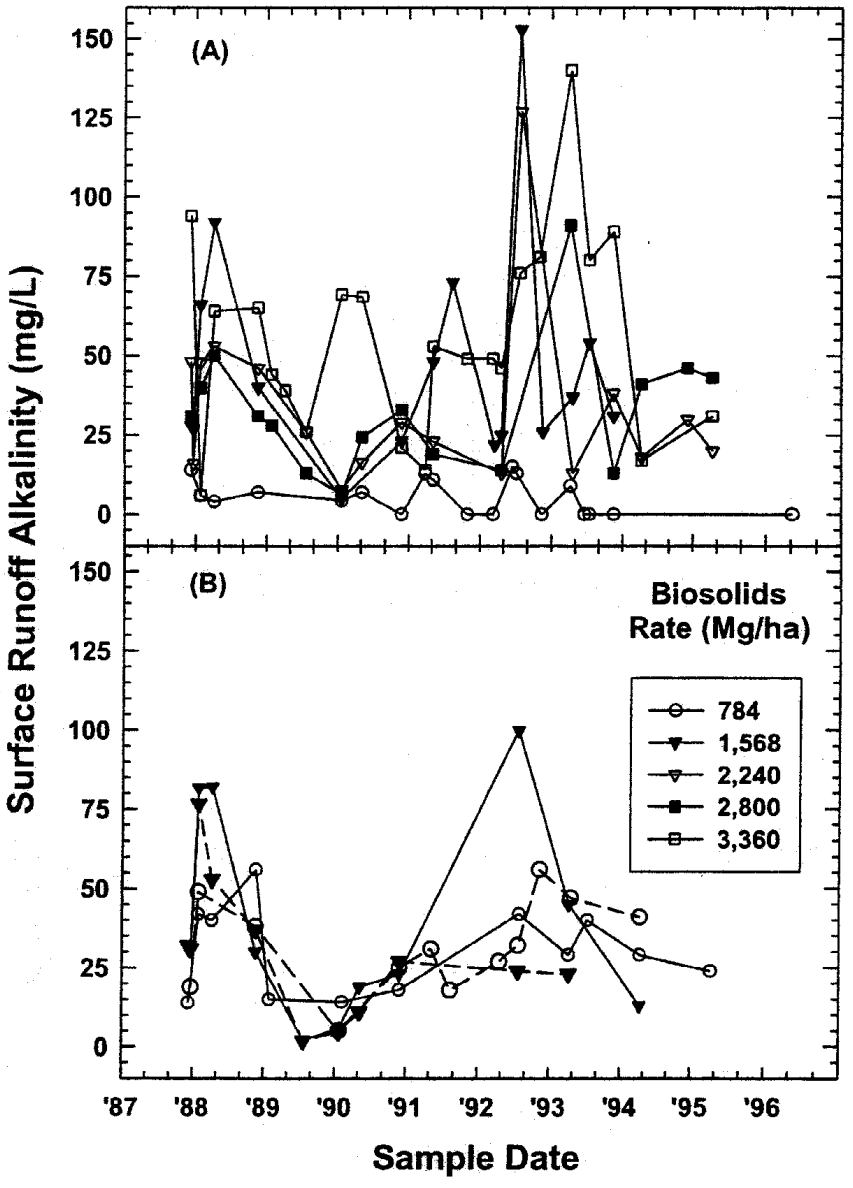
ACIDITY OF SURFACE WATER RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY. THE INSERT SHOWS DATA FOR THE UNAMENDED PLOT



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 38

ALKALINITY OF SURFACE WATER RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



plot. In all the plots, alkalinity fluctuated widely, and in most years the alkalinity was lowest in the unlimed plot of the 784 Mg/ha biosolids rate. There was no consistent effect of biosolids loading rate, lime, or clay on surface runoff alkalinity.

SURFACE WATER BOD_5, SUSPENDED SOLIDS, AND SOLUBLE SALTS

A summary of BOD_5, suspended solids, and soluble salts in the surface water runoff is presented in Table 10. For the 784 and 1,568 Mg/ha biosolids rates, data for the limed plots were summarized as the mean for the plots with and without clay. The levels of TSS, TDS, and SO_4 in the amended plots were much lower than in the unamended plot. The EC levels were also highest in the unamended plot. The concentrations of Cl tended to increase with biosolids application rate. There were no consistent effects of biosolids loading rate on the levels of these surface runoff constituents. The levels of TDS, EC, Cl, and SO_4 tended to be higher at the biosolids application rate of 3,360 Mg/ha than in the other treatments, but these levels were lower than those observed in the unamended plot.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 10

SUMMARY OF BOD_5, TOTAL SUSPENDED SOLIDS (TSS), AND CONCENTRATIONS OF SALTS IN SURFACE RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY AND BIOSOLIDS + LIME

Biosolids	No Lime			Limed (179 Mg/ha)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
(Mg/ha)			BOD_5 (mg/L)			
0	0.0	104	9.6			
784	0.0	50	5.9	0.0	52	8.1
1,568	0.0	15	6.7	2.0	23	9.2
2,240	0.0	40	11.3			
2,800	0.0	20	8.0			
3,360	0.0	27	10.2			
			TSS (mg/L)			
0	215	158,740	21,815			
784	15	6,585	520	10	795	152
1,568	8.0	314	65	0.0	596	101
2,240	2.0	544	114			
2,800	2.0	1,076	147			
3,360	6.0	1,024	124			
			TDS (mg/L)			
0	1,229	80,764	10,570			
784	42	6,509	1,453	37	2377	703
1,568	3.0	2,758	611	21	2410	656
2,240	32	3,661	794			
2,800	22	4,246	713			
3,360	65	12,075	2,854			
			EC (dS/m)			
0	1.70	9.70	3.33			
784	0.02	2.10	0.72	0.02	2.10	0.72
1,568	0.03	1.89	0.67	0.03	1.89	0.67
2,240	0.05	2.34	0.60			
2,800	0.03	3.11	0.73			
3,360	0.04	9.05	2.53			

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 10 (Continued)

SUMMARY OF BOD_5, TOTAL SUSPENDED SOLIDS (TSS), AND CONCENTRATIONS OF SALTS IN SURFACE RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY AND BIOSOLIDS + LIME

Biosolids	No Lime			Limed (179 Mg/ha)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
(Mg/ha)	----------	----------	Cl (mg/L)	----------	----------	----------
0	0.2	34	7.7			
784	0.0	42	6.1	0.0	76	9.4
1,568	1.0	51	10	0.0	81	14
2,240	0.0	67	14			
2,800	0.8	600	50			
3,360	2.3	682	111			
	----------	----------	SO_4 (mg/L)	----------	----------	----------
0	870	10,840	3,133			
784	18	2,684	723	1.8	1,428	386
1,568	1.7	1,573	429	1.0	11,700	1,036
2,240	2.0	3,180	477			
2,800	1.0	2,930	374			
3,360	3.0	7,570	1,144			

SURFACE WATER NUTRIENTS

The concentrations of nutrients (NH_3-N, NO_3-N, and total P) in the surface water runoff are presented in Figures 39 through 41. In all the plots, the concentrations of those nutrients fluctuated during the study, and in the amended plots most of the highest concentrations occurred during the earliest period of the study. For NH_3-N (Figure 39) and NO_3-N (Figure 40), most of the occurrences of elevated levels ("spikes") were in the unamended plot (NH_3-N only) and at the 3,360 Mg/ha biosolids loading rate (NH_3-N and NO_3-N). Most of the occurrences of elevated total P concentrations ("spikes") occurred in the unamended plot. During the 1994 to 1996 period, when the last surface runoff samples were collected from the plots, concentrations in the amended plots were less than 2 mg/kg NH_3-N (Figure 39), less than 40 mg/L NO_3-N (Figure 40), and less than 5 mg/L total P (Figure 41). There were no consistent differences between the limed and unlimed plots and between the plots with and without clay (Figure 39B, 40B, and 41B).

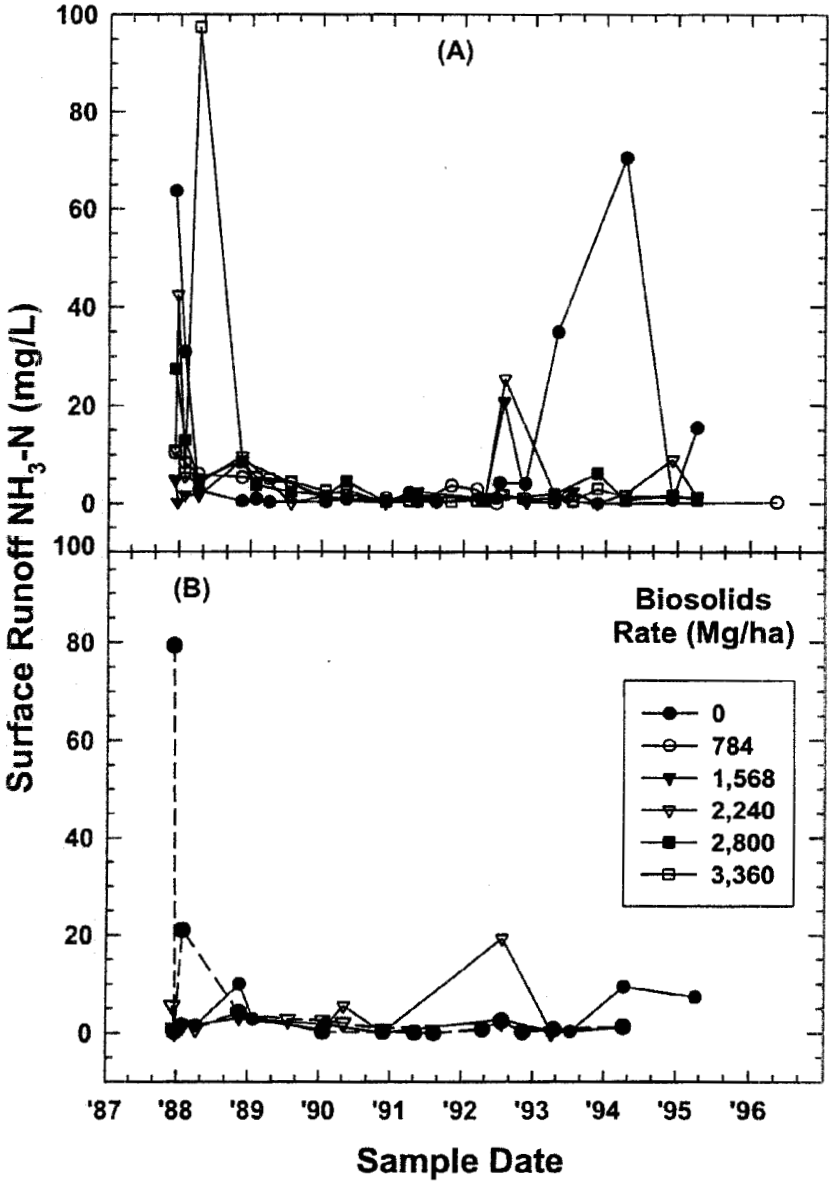
SURFACE WATER METALS

The maximum and mean concentrations of metals in the surface water runoff are presented in Table 11. For the 784 and

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 39

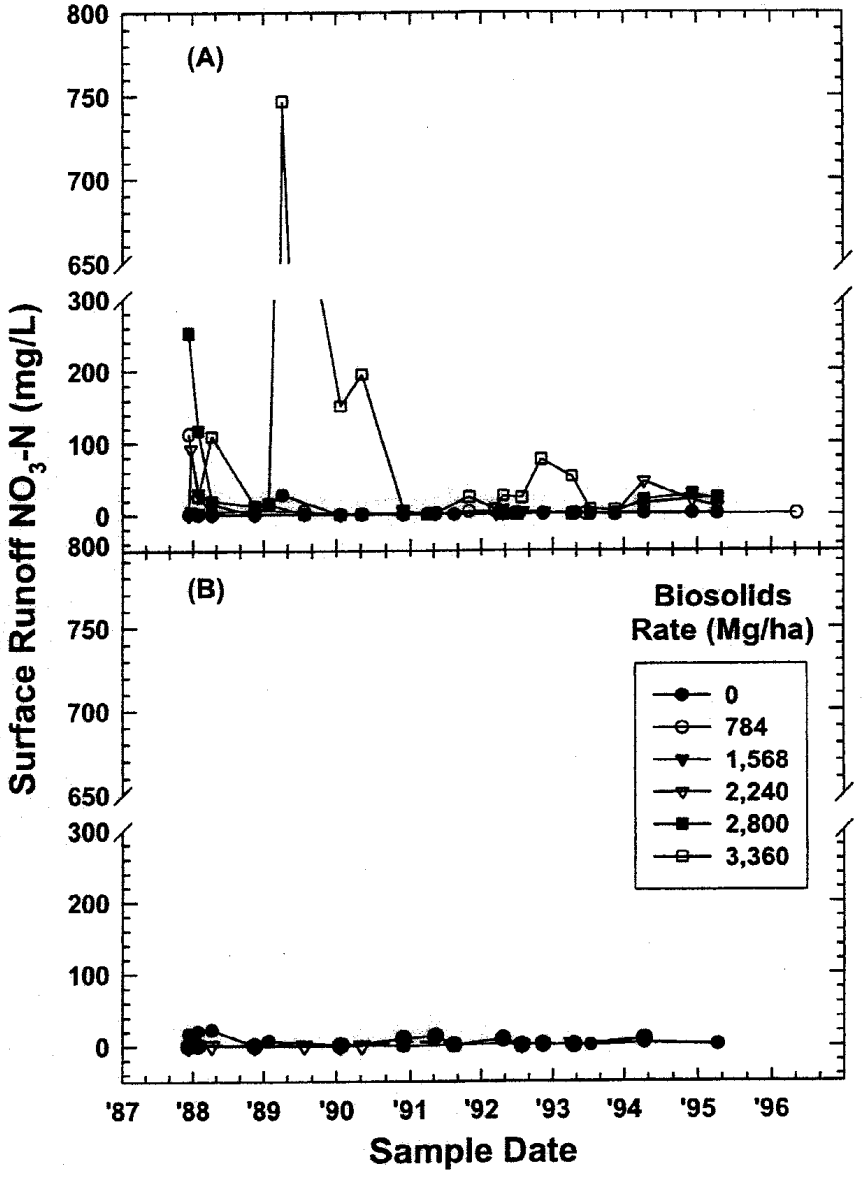
AMMONIA-N IN SURFACE WATER RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 40

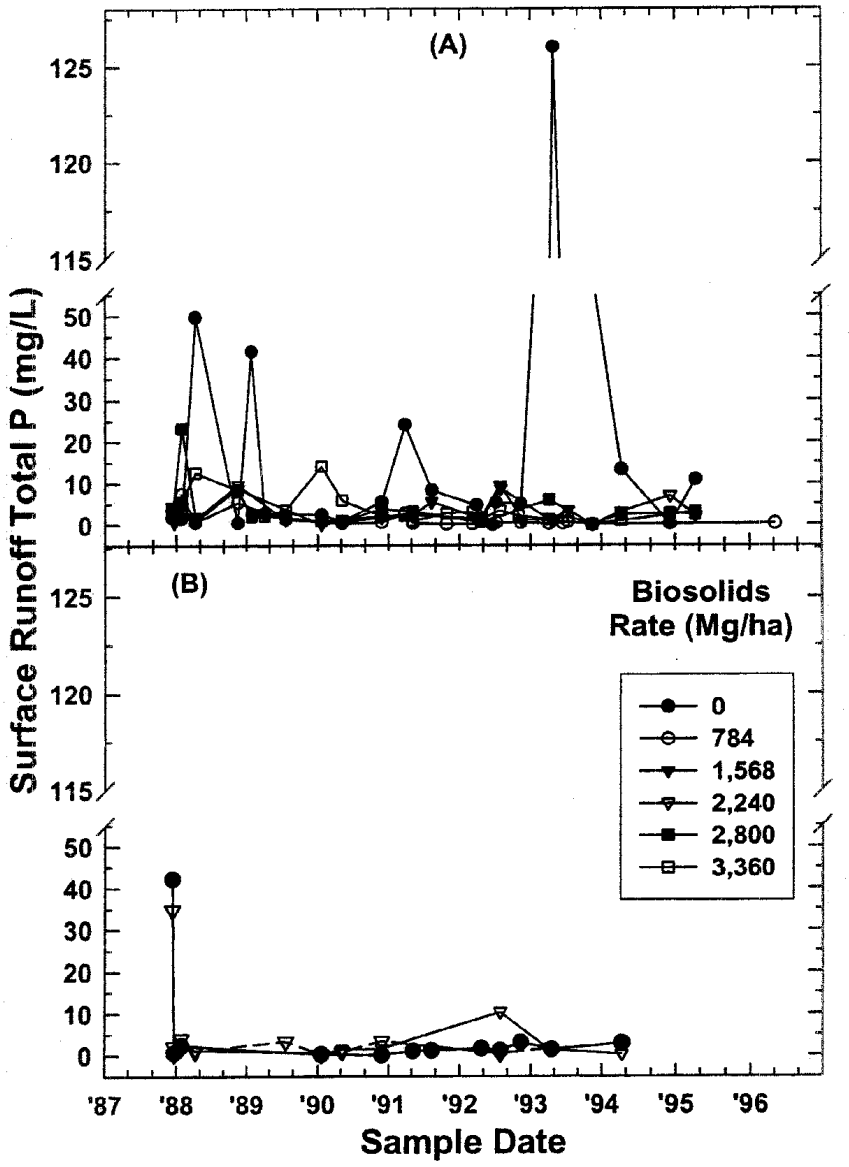
NITRATE-N IN SURFACE WATER RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

FIGURE 41

TOTAL P IN SURFACE WATER RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY (A) AND BIOSOLIDS + LIME (B) WITHOUT (SOLID LINES) AND WITH (BROKEN LINES) CLAY



METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 11

SUMMARY[1] OF METAL CONCENTRATIONS IN SURFACE RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY AND BIOSOLIDS + LIME

Biosolids	No Lime		Limed (179 Mg/ha)	
	Maximum	Mean	Maximum	Mean
(Mg/ha)	----------Al (mg/L)----------			
0	440	98.6		
784	13	2.1	4.0	0.87
1,568	3.0	0.7	5.0	0.79
2,240	3.0	0.75		
2,800	10	1.4		
3,360	3.0	0.90		
	----------Cd (mg/L)----------			
0	1.8	0.31		
784	0.22	0.06	0.08	0.01
1,568	0.09	0.01	0.09	0.01
2,240	0.09	0.01		
2,800	0.20	0.02		
3,360	0.20	0.04		
	----------Cr (mg/L)----------			
0	7.7	0.60		
784	0.23	0.03	0.32	0.03
1,568	0.25	0.03	0.21	0.02
2,240	0.14	0.02		
2,800	1.32	0.13		
3,360	0.23	0.03		

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 11 (Continued)

SUMMARY[1] OF METAL CONCENTRATIONS IN SURFACE RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY AND BIOSOLIDS + LIME

Biosolids	No Lime		Limed (179 Mg/ha)	
	Maximum	Mean	Maximum	Mean
(Mg/ha)	----------Cu (mg/L)----------			
0	2.7	0.41		
784	0.44	0.09	0.27	0.06
1,568	0.29	0.06	0.31	0.06
2,240	0.34	0.08		
2,800	1.29	0.20		
3,360	0.87	0.27		
	----------Fe (mg/L)----------			
0	38	6.3		
784	3.6	1.0	1.0	0.17
1,568	0.88	0.1	0.86	0.15
2,240	1.1	0.2		
2,800	2.7	0.4		
3,360	11	1.5		
	----------Mn (mg/L)----------			
0	8,600	1,106		
784	47	4.5	23	2.6
1,568	9.6	1.1	13	1.2
2,240	10	1.4		
2,800	30	3.0		
3,360	11	1.2		

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 11 (Continued)

SUMMARY[1] OF METAL CONCENTRATIONS IN SURFACE RUNOFF FROM COAL REFUSE AMENDED WITH BIOSOLIDS ONLY AND BIOSOLIDS + LIME

Biosolids	No Lime		Limed (179 Mg/ha)	
	Maximum	Mean	Maximum	Mean
(Mg/ha)	----------Ni (mg/L)----------			
0	3.2	0.64		
784	0.60	0.15	0.30	0.03
1,568	0.40	0.05	0.40	0.05
2,240	0.40	0.08		
2,800	0.70	0.12		
3,360	1.70	0.33		
	----------Pb (mg/L)----------			
0	26	1.6		
784	0.23	0.02	0.14	0.02
1,568	0.18	0.02	0.13	0.02
2,240	0.11	0.01		
2,800	0.55	0.05		
3,360	0.11	0.01		
	----------Zn (mg/L)----------			
0	190	31		
784	10	2.9	1.1	0.17
1,568	1.5	0.23	0.60	0.14
2,240	1.1	0.24		
2,800	2.6	0.33		
3,360	3.6	0.62		

[1]Minimum concentrations observed for all metals were below their detection limits.

1,568 Mg/ha biosolids rates, data for the limed plots were summarized as the mean for the plots with and without clay. The minimum concentrations of all the metals were below their detection limits. The concentrations of all metals (especially Al, Fe, Mn, and Zn) were higher in the unamended plot than in the amended plots. In the amended plots, the mean concentrations of Cd, Cu, Ni, and Zn were higher at the 784 Mg/ha biosolids application rate than at the 1,568 Mg/ha biosolids application rate. The mean concentrations of Fe, Cu, Ni, and Zn tended to be higher in surface runoff from the 3,360 Mg/ha biosolids-amended plot than from other amended plots. At the 784 and 1,568 Mg/ha biosolids application rates, mean concentrations of Al, Cd, Cu, and Zn were usually lower in the limed plots than in the unlimed plots.

DISCUSSION

The biosolids and biosolids plus lime amendments sustained the long-term amelioration of the coal refuse to conditions suitable for plant growth by decreasing the soil acidity and increasing the availability of essential plant nutrients. The 784 and 1,568 Mg/ha biosolids application rates were more effective when they were applied together with 179 Mg/ha lime as compared to when the biosolids were applied without lime. However, the effectiveness of the biosolids treatments at rates greater than 1,568 Mg/ha without lime was similar or greater than the treatments where lower biosolids rates were applied together with lime. The effect of biosolids on pH and acidity of the coal refuse was most prominent at the surface, where the amendments were applied, then decreased with depth in the profile.

Pietz et al. (1989a) compared treatments that included combinations of biosolids (542 Mg/ha), lime (90 Mg/ha), and gypsum (112 Mg/ha) for reclamation of coal refuse at the same site where the current study was conducted. They found that the biosolids plus lime amendment was the most effective in controlling acidity and pH in the 0- to 15-cm depth of the coal refuse, with an acidity less than 2 $cmol_c/kg$ and a pH of

approximately 5.0. The authors concluded that the effectiveness of the treatments might be greater at higher biosolids application rates. Throughout the current study, the treatments of 784 and 1,568 Mg/ha biosolids application rates plus lime maintained the pH between 5.9 - 7.0 (Figure 3) and the acidity to less than 2.0 $cmol_c/kg$ in the 0- to 15-cm depth of the coal refuse.

Except for the higher concentrations of Cu and Pb in 1988, the concentrations of metals in the forage tissue were within the range found in forage grown in coal refuse amended with biosolids and gypsum (Pietz et al., 1989b). The decrease in concentrations of metals in the forage tissue after the initial response to the treatments is indicative of a decrease in the bioavailability of the biosolids-applied metals with time. This response was similar to the observations of Sopper (1993). Except for Cr (1987) and Cd, the concentrations of metals in the forage tissue were lower than the suggested permissible levels for trace metals in agronomic crops (Sopper, 1993).

The relatively high concentrations of Cd in the forage tissue were due to the relatively high concentration of Cd in the biosolids used in the study (76 mg Cd/kg; Table 2). Concentrations of Cd in biosolids currently produced at the

District are usually less than 5 mg Cd/kg. Therefore, if current District biosolids are applied to non-acidic soils at even higher rates than those used in this study, it is quite unlikely that Cd levels in the crops will exceed the permissible or phytotoxic levels. The transfer of metals from the applied biosolids to forage tissue observed in this study was lower than that predicted for forage in Pathway 6 of the USEPA Part 503 risk assessment model.

The suitability and application rate of amendments for reclamation of disturbed lands such as coal refuse material requires an evaluation of the benefits and impacts associated with the amendments. The primary benefits derived from the biosolids used for reclamation of the coal refuse were: (1) they increased the pH and reduced acidity, (2) they increased availability of essential plant nutrients, and (3) they increased organic matter content which improved the physical properties of the soil. The potential negative impacts of biosolids in land reclamation were initially the excessive levels of soluble salts and nutrients at the high loading rates.

In this study, the biosolids amendments ameliorated the coal refuse and improved the plant root environment by decreasing the acidity, increasing the pH, and decreasing the

salinity. In the amended plots, the EC levels in the root zone tended to increase with the biosolids application rate during the first two years, but with time the soluble salts were leached to the lower depths and the EC in treatments merged to almost similar levels. Therefore, the soluble salt content of biosolids is not a major long-term concern for reclamation and revegetation of coal refuse.

The high concentrations of nutrients in biosolids presents a potential concern for off-site movement by leaching and surface runoff. Immediately following biosolids applications, surface runoff is a pathway for potential off-site losses of soluble NH_3-N, NO_3-N and P, and NO_3-N is prone to leaching. Within a few years after biosolids application, the organic matter and slowly soluble P compounds replenish the soluble levels of these nutrients, minimizing the potential for losses. The potential for off-site movement of nutrients associated with biosolids application is directly related to loading rates.

Therefore, in developing the recommended rates of biosolids application for the reclamation of disturbed lands, such as coal refuse piles, the loading rate should be tailored to minimize the potential for detrimental impacts on the watershed while optimizing the root zone for establishing

vegetation and maintaining it for the long term. In this regard, it is important to also consider the potential for leaching and surface runoff of nutrients and metals when applying biosolids because with time the established vegetation will reduce the surface water runoff and leaching.

For reclamation of coal refuse with forage vegetation, as used in this study, most of the plant roots are in the upper 30-cm (root zone) of the coal refuse. Therefore, amelioration of this layer can be considered as a sufficient reclamation goal. Throughout the study, the treatment receiving 1,568 Mg/ha biosolids plus 179 Mg/lime was nearly as effective in ameliorating the upper 30-cm soil layer and maintaining the pH, acidity, and EC as the higher biosolids loading rates.

Among the treatments tested in this study, the 1,568 Mg/ha biosolids plus 179 Mg/ha of lime treatment would be recommended for reclamation of coal refuse under similar site conditions and goals. This treatment presents the best combination for effectively reclaiming the coal refuse and minimizing the potential for excessive losses of nutrients through surface runoff and leaching.

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APPENDIX AI

CONCENTRATIONS OF CONSTITUENTS IN COAL REFUSE

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-1

COAL REFUSE pH IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	2.1	4.7	6.0	6.7	6.4	6.6	6.8	6.1	6.3	6.5
1988	2.3	5.1	6.8	6.9	6.5	7.0	7.2	5.9	6.3	6.1
1989	2.2	4.4	6.8	7.0	6.0	6.8	7.0	5.4	6.1	6.0
1990	2.3	5.2	6.6	6.8	6.4	6.8	7.0	6.2	6.4	6.2
1991	2.2	4.5	6.3	6.2	6.2	6.6	7.1	6.0	6.3	6.3
1992	2.3	4.6	6.5	7.0	6.3	6.7	6.7	6.4	6.6	6.2
1993	2.4	4.7	6.4	6.9	6.0	6.7	6.9	6.1	6.3	6.2
1994	2.2	5.2	6.4	6.6	5.8	6.5	7.0	5.9	6.2	6.3
1995	2.3	4.5	6.7	6.8	5.9	6.6	7.0	6.3	6.4	6.1
1996	2.2	4.5	6.4	6.7	6.2	6.8	7.0	6.6	6.6	6.2
1997	2.4	4.8	6.3	6.8	6.2	6.6	7.0	6.2	6.6	6.6
1998	2.4	4.8	6.5	7.0	6.1	6.6	7.2	6.2	6.7	6.5
1999	2.2	4.0	7.0	7.0	6.7	6.8	7.4	6.5	6.5	6.6
2000	2.2	4.5	6.8	7.1	6.2	6.7	7.2	6.3	6.6	6.7

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-1 (Continued)

COAL REFUSE pH IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	15 to 30 cm									
1987	2.2	2.8	5.5	4.8	4.2	5.8	6.5	5.2	6.6	6.6
1988	2.3	4.3	5.1	6.1	4.6	6.0	6.2	4.8	6.4	6.2
1989	2.2	2.8	5.0	6.4	4.2	5.2	6.8	4.2	5.8	6.2
1990	2.2	4.1	4.2	6.5	4.6	6.0	7.1	5.1	5.5	5.3
1991	2.1	3.2	2.9	6.8	4.4	5.7	6.9	4.6	5.7	5.6
1992	2.1	3.4	4.6	6.1	4.8	5.9	6.8	5.7	6.0	5.8
1993	2.2	4.8	4.5	6.1	3.8	5.3	6.8	5.2	5.5	5.4
1994	2.1	3.9	5.7	6.3	3.2	6.6	6.7	5.0	5.9	5.4
1995	3.2	2.4	5.3	6.4	4.7	5.9	7.2	5.1	5.5	5.5
1996	2.2	2.9	4.6	6.1	4.6	5.6	7.2	5.7	6.0	5.6
1997	2.4	3.1	5.8	6.4	4.9	6.2	6.9	5.6	6.6	6.0
1998	2.4	3.1	4.8	6.4	3.8	6.2	7.0	5.0	6.1	5.6
1999	2.2	3.8	3.7	7.0	4.7	5.7	7.2	5.6	6.0	6.0
2000	2.0	3.8	4.2	6.0	4.6	5.6	6.9	5.3	6.4	6.7

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-1 (Continued)

COAL REFUSE pH IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	30 to 45 cm[1]									
1987							5.0	3.8	5.1	5.8
1988							4.1	5.5	5.2	5.6
1989							6.2	4.8	4.7	6.2
1990							4.3	3.7	5.2	5.7
1991							4.8	3.7	4.6	5.7
1992							5.8	4.1	5.1	6.7
1993							5.7	3.9	5.2	5.3
1994							6.2	3.3	5.9	5.3
1995							5.0	3.1	4.0	4.9
1996							6.0	4.4	4.9	5.5
1997							4.3	3.7	5.5	5.5
1998							6.0	4.9	4.6	4.9
1999							4.5	3.8	5.2	3.6
2000							5.0	4.8	5.4	6.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-1 (Continued)

COAL REFUSE pH IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	45 to 60 cm[1]									
1987									3.6	4.4
1988									3.4	4.8
1989									3.1	5.4
1990									3.6	5.7
1991									4.8	6.1
1992									3.9	6.6
1993									4.7	5.1
1994									4.4	6.3
1995									3.4	5.5
1996									4.8	6.6
1997									5.9	5.8
1998									4.2	6.0
1999									6.4	4.7
2000									5.0	6.3

[1]Plots with no data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2

COAL REFUSE EC (dS/m) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	0.51	0.40	0.36	0.30	0.27	0.24	0.26	0.32	0.44	0.30
1988	0.54	0.32	0.28	0.26	0.32	0.28	0.31	0.53	0.52	0.65
1989	0.63	0.30	0.27	0.27	0.33	0.28	0.27	0.30	0.48	0.42
1990	0.56	0.27	0.27	0.27	0.28	0.27	0.23	0.31	0.29	0.30
1991	0.56	0.27	0.23	0.25	0.25	0.24	0.10	0.24	0.28	0.27
1992	0.57	0.28	0.24	0.28	0.24	0.20	0.26	0.21	0.28	0.33
1993	0.51	0.27	0.27	0.27	0.28	0.27	0.12	0.26	0.26	0.27
1994	0.71	0.28	0.26	0.23	0.27	0.27	0.08	0.26	0.26	0.29
1995	0.58	0.24	0.23	0.23	0.26	0.24	0.07	0.18	0.11	0.27
1996	0.64	0.27	0.24	0.24	0.25	0.20	0.06	0.06	0.05	0.25
1997	0.49	0.25	0.26	0.24	0.25	0.22	0.06	0.16	0.07	0.15
1998	0.54	0.26	0.26	0.17	0.27	0.28	0.06	0.25	0.06	0.20
1999	0.55	0.19	0.14	0.14	0.14	0.14	0.05	0.12	0.13	0.14
2000	0.65	0.21	0.20	0.14	0.21	0.20	0.08	0.19	0.18	0.22

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2 (Continued)

COAL REFUSE EC (dS/m) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	15 to 30 cm									
1987	0.52	0.41	0.38	0.31	0.34	0.33	0.30	0.38	0.45	0.50
1988	0.56	0.35	0.31	0.32	0.40	0.33	0.32	0.45	0.63	0.50
1989	0.62	0.43	0.31	0.33	0.35	0.29	0.31	0.32	0.57	0.61
1990	0.71	0.29	0.29	0.27	0.31	0.28	0.26	0.39	0.34	0.34
1991	0.68	0.31	0.29	0.24	0.28	0.23	0.25	0.27	0.35	0.38
1992	0.74	0.32	0.27	0.28	0.30	0.26	0.26	0.26	0.32	0.34
1993	0.73	0.28	0.28	0.28	0.29	0.26	0.28	0.28	0.31	0.27
1994	0.84	0.29	0.26	0.25	0.30	0.27	0.26	0.27	0.27	0.29
1995	0.27	0.49	0.24	0.24	0.25	0.24	0.22	0.23	0.25	0.25
1996	0.74	0.31	0.24	0.24	0.27	0.25	0.23	0.25	0.24	0.25
1997	0.57	0.28	0.24	0.24	0.29	0.26	0.25	0.25	0.24	0.25
1998	0.57	0.30	0.25	0.26	0.29	0.26	0.25	0.24	0.26	0.26
1999	0.46	0.21	0.21	0.13	0.18	0.14	0.13	0.15	0.14	0.14
2000	0.83	0.21	0.21	0.20	0.22	0.20	0.21	0.21	0.20	0.22

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2 (Continued)

COAL REFUSE EC (dS/m) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	30 to 45 cm									
1987							0.29	0.30	0.40	0.40
1988							0.30	0.33	0.47	0.41
1989							0.31	0.34	0.52	0.70
1990							0.31	0.37	0.58	0.35
1991							0.26	0.30	0.40	0.44
1992							0.27	0.27	0.40	0.39
1993							0.28	0.25	0.32	0.30
1994							0.26	0.29	0.31	0.36
1995							0.23	0.27	0.28	0.27
1996							0.23	0.24	0.25	0.26
1997							0.24	0.25	0.26	0.29
1998							0.24	0.24	0.29	0.27
1999							0.18	0.22	0.16	0.24
2000							0.21	0.21	0.20	0.22

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-2 (Continued)

COAL REFUSE EC (dS/m) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	45 to 60 cm									
1987										
1988									0.29	0.33
1989									0.35	0.45
1990									0.56	0.50
1991									0.43	0.40
1992									0.33	0.46
1993									0.42	0.43
1994									0.31	0.32
1995									0.32	0.46
1996									0.29	0.28
1997									0.24	0.27
1998									0.27	0.30
1999									0.28	0.29
2000									0.14	0.24
									0.23	0.22

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-3

COAL REFUSE ORGANIC CARBON (%) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	6.42	8.76	8.18	5.74	9.64	8.80	6.92	12.28	12.23	10.89
1988	5.58	8.22	6.82	5.20	7.99	7.76	4.62	10.54	10.98	10.70
1989	5.60	7.43	7.47	4.70	7.93	7.44	6.30	9.43	10.08	10.02
1990	5.68	9.18	6.91	5.34	7.86	7.31	6.83	11.14	10.72	10.31
1991	4.95	6.20	6.36	5.70	7.39	7.06	5.77	10.28	11.06	10.56
1992	4.34	6.50	7.67	3.94	7.71	7.31	6.22	10.44	10.41	8.91
1993	4.56	7.10	7.44	4.13	7.35	6.43	5.73	10.77	10.54	9.69
1994	5.35	8.03	8.05	6.12	7.04	7.20	5.24	9.55	9.97	8.98
1995	5.24	6.61	6.79	6.12	7.57	6.53	3.49	10.21	10.13	9.35
1996	4.65	6.86	6.85	5.31	7.71	6.42	4.19	10.33	9.68	8.95
1997	6.21	7.72	7.64	4.56	8.08	7.32	5.02	9.78	9.63	9.84
1998	5.58	8.01	7.02	4.58	7.00	6.92	5.16	9.21	10.29	9.20
1999	4.54	6.32	7.40	4.52	7.68	6.75	4.56	10.24	9.32	9.52
2000	5.42	6.32	5.89	4.92	6.48	6.34	3.68	9.06	9.22	8.18

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-3 (Continued)

COAL REFUSE ORGANIC CARBON (%) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	15 to 30 cm									
1987	6.22	5.69	5.87	5.22	5.84	5.42	5.80	7.80	11.23	9.90
1988	5.51	4.70	5.88	4.21	5.60	5.41	5.45	6.40	8.65	8.06
1989	5.44	4.61	4.98	4.23	5.23	4.54	4.84	6.40	8.16	9.41
1990	5.68	5.80	4.41	4.16	4.72	4.44	4.60	7.76	7.88	7.09
1991	5.86	4.28	4.89	4.56	5.18	4.22	4.72	6.59	8.96	7.78
1992	4.69	3.75	4.88	4.67	5.20	4.13	4.65	8.66	9.52	7.36
1993	4.65	4.26	5.60	3.78	4.18	4.59	3.53	8.20	7.87	7.02
1994	6.10	4.97	4.28	4.97	3.79	5.31	4.70	6.83	8.51	5.85
1995	5.02	5.24	4.72	3.82	5.44	3.90	3.79	7.37	7.37	7.09
1996	5.21	5.29	5.85	4.64	5.10	3.67	3.38	7.65	9.27	7.40
1997	5.03	5.71	5.42	4.56	6.10	4.82	4.84	8.86	8.59	7.80
1998	6.59	5.70	6.56	4.55	4.64	3.91	5.62	6.85	7.86	7.04
1999	4.75	5.50	4.18	4.90	4.78	5.07	3.90	7.58	7.98	6.97
2000	5.82	4.66	4.62	3.46	4.24	4.00	4.98	5.74	7.89	5.24

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-3 (Continued)

COAL REFUSE ORGANIC CARBON (%) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	30 to 45 cm[1]									
1987							5.36	4.59	7.18	8.10
1988							5.06	4.73	6.74	6.10
1989							5.54	5.90	6.72	7.84
1990							4.55	5.48	8.34	6.24
1991							4.74	5.62	5.97	7.54
1992							4.25	4.83	5.03	5.78
1993							5.16	5.65	6.64	5.06
1994							4.34	5.05	7.22	6.96
1995							4.81	5.05	5.91	5.91
1996							5.15	5.12	6.26	5.42
1997							4.88	5.88	6.28	6.65
1998							5.55	5.67	5.50	4.81
1999							4.45	4.84	5.89	5.62
2000							4.66	5.58	5.34	4.76

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-3 (Continued)

COAL REFUSE ORGANIC CARBON (%) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	45 to 60 cm[1]									
1987									5.42	5.75
1988									4.38	5.84
1989									4.05	6.15
1990									5.74	5.24
1991									4.89	5.84
1992									4.58	5.66
1993									4.39	4.79
1994									4.76	5.71
1995									5.57	4.96
1996									4.42	4.24
1997									4.51	5.50
1998									4.71	5.02
1999									6.36	5.44
2000									5.22	4.62

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-4

COAL REFUSE WATER-SOLUBLE ACIDITY ($cmol_c/kg$) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	13.50	0.70	0.20	0.00	0.00	0.00	0.20	0.40	1.00	0.60
1988	13.50	1.00	0.04	1.00	1.50	1.00	0.00	0.50	0.35	0.10
1989	9.43	0.54	0.09	0.09	0.19	0.13	0.07	0.24	0.29	0.40
1990	17.05	0.20	0.00	0.00	0.10	0.02	0.31	0.39	0.50	0.57
1991	12.30	0.36	0.01	0.03	0.06	0.01	0.00	0.10	0.10	0.20
1992	8.67	0.33	0.27	0.06	0.03	0.02	0.04	0.15	0.00	0.70
1993	5.67	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.06
1994	3.40	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
1995	14.43	0.34	0.06	0.01	0.11	0.07	0.01	0.10	0.08	0.06
1996	12.88	0.14	0.00	0.25	0.00	0.00	0.00	0.00	0.03	0.15
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-4 (Continued)

COAL REFUSE WATER-SOLUBLE ACIDITY ($cmol_c/kg$) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	15 to 30 cm									
1987	14.20	5.10	0.40	0.00	0.20	0.00	0.00	0.70	0.80	0.70
1988	14.50	1.50	1.00	1.00	2.00	1.00	0.00	0.45	0.50	0.70
1989	8.34	2.34	0.13	0.02	0.72	0.15	0.01	0.86	0.21	0.36
1990	16.01	0.53	0.43	0.00	0.40	0.00	0.20	0.50	0.57	0.66
1991	16.95	1.98	1.96	0.00	0.39	0.06	0.00	0.29	0.19	0.27
1992	9.74	0.99	0.43	6.00	0.07	0.02	0.04	0.29	0.24	0.00
1993	10.41	0.00	0.06	0.00	0.37	0.00	0.00	0.02	0.64	0.12
1994	5.15	0.20	0.00	0.00	0.46	0.00	0.00	0.02	0.01	0.01
1995	11.08	1.43	0.10	0.00	0.29	0.00	0.01	0.23	0.06	0.11
1996	15.04	2.62	0.11	0.00	0.40	0.00	0.00	0.08	0.26	0.19

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-4 (Continued)

COAL REFUSE WATER-SOLUBLE ACIDITY ($cmol_c/kg$) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	30 to 45 cm[1]									
1987							0.20	1.50	0.60	0.70
1988							ND[2]	ND	ND	ND
1989							0.09	0.22	0.51	1.36
1990							0.50	1.39	0.56	0.23
1991							0.11	0.90	0.27	0.79
1992							0.11	0.47	0.28	0.06
1993							0.00	0.62	0.65	0.26
1994							0.00	0.18	0.01	0.02
1995							0.09	1.35	1.38	0.15
1996							0.11	0.43	0.99	0.47

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-4 (Continued)

COAL REFUSE WATER-SOLUBLE ACIDITY ($cmol_c/kg$) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	45 to 60 cm[1]									
1987										
1988									0.28	1.00
1989									0.00	0.00
1990									5.53	1.41
1991									2.72	0.27
1992									0.09	0.66
1993									0.78	0.32
1994									0.62	0.57
1995									0.07	0.14
1996									1.07	0.21
									0.51	0.07

[1]Plots with missing data were not monitored at these depths.
[2]ND = No data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-5

COAL REFUSE KCl-EXTRACTABLE ACIDITY[1] ($cmol_c/kg$) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	7.30	0.40	0.40	0.10	0.20	0.20	0.30	0.20	0.50	0.40
1988	9.75	1.40	0.70	0.55	0.50	0.35	0.15	0.35	0.25	0.25
1989	6.23	0.87	0.21	0.20	0.22	0.18	0.21	0.25	0.17	0.20
1990	6.74	0.38	0.22	0.19	0.18	0.15	0.15	0.17	0.52	0.13
1991	6.67	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	ND[2]	1.99	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
1993	6.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	1.41	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	6.41	0.34	0.02	0.00	0.00	0.00	0.00	0.04	0.00	0.00
1996	7.25	0.03	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.07
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-5 (Continued)

COAL REFUSE KCl-EXTRACTABLE ACIDITY[1] ($cmol_c/kg$) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	15 to 30 cm									
1987	6.60	4.90	0.40	0.10	0.20	0.20	0.10	0.40	0.60	0.40
1988	7.25	1.60	0.85	0.70	0.85	1.25	0.00	0.35	0.35	0.35
1989	5.79	3.05	0.36	0.42	0.78	0.29	0.61	1.33	0.21	0.19
1990	6.49	0.57	0.20	0.29	0.21	0.19	0.12	0.14	0.22	0.27
1991	9.00	2.11	2.39	0.07	0.00	0.00	0.00	0.00	0.00	0.00
1992	ND[2]	31.19	3.16	0.00	0.15	0.02	0.01	0.00	0.06	0.00
1993	5.73	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
1994	1.75	0.22	0.00	0.00	0.46	0.00	0.00	0.01	0.00	0.00
1995	5.65	2.12	0.02	0.03	0.00	0.00	0.00	0.01	0.00	0.00
1996	6.49	5.06	0.06	0.00	0.15	0.07	0.00	0.01	0.00	0.04
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-5 (Continued)

COAL REFUSE KCl-EXTRACTABLE ACIDITY[1] ($cmol_c/kg$) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	----------30 to 45 cm^3----------									
1987							0.20	0.40	0.20	0.50
1988							ND	ND	ND	ND
1989							0.46	0.55	0.52	0.41
1990							0.78	1.62	0.28	0.34
1991							0.00	0.29	0.00	0.26
1992							0.05	10.34	0.00	0.00
1993							0.00	0.53	0.01	0.00
1994							0.00	0.31	0.00	0.00
1995							0.12	1.93	0.39	0.00
1996							0.00	0.42	0.01	0.03
1997							0.00	0.00	0.00	0.00
1998							0.00	0.00	0.00	0.00
1999							0.00	0.00	0.00	0.00
2000							0.00	0.00	0.00	0.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-5 (Continued)

COAL REFUSE KCl-EXTRACTABLE ACIDITY[1] ($cmol_c/kg$) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	45 to 60 cm^3									
1987										
1988									0.80	1.00
1989									0.00	0.00
1990									4.25	0.71
1991									3.02	0.31
1992									0.00	0.01
1993									0.06	0.01
1994									0.11	0.00
1995									0.10	0.02
1996									1.06	0.02
1997									0.61	0.04
1998									0.00	0.00
1999									0.00	0.00
2000									0.00	0.00
									0.00	0.00

[1]Sequentially extracted in water and then in 1 M KCl.
[2]ND = No data.
[3]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-6

COAL REFUSE KCl-EXTRACTABLE Al (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
0 to 15 cm										
1987	208.5	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	6.0	10.0
1988	119.0	<10.0	<10.0	29.5	58.5	<10.0	<10.0	<10.0	<10.0	10.0
1989	169.5	4.5	<10.0	<10.0	<10.0	<10.0	<2.0	<2.0	4.5	1.5
1990	116.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1991	139.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1992	117.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1993	261.5	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1994	177.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1995	82.0	1.2	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1996	57.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.0
15 to 30 cm										
1987	206.5	227.5	<10.0	<10.0	<10.0	<10.0	<10.0	0.5	8.0	10.0
1988	107.5	<10.0	24.0	55.0	67.0	<10.0	<10.0	<10.0	<10.0	10.0
1989	149.5	105.5	<10.0	<10.0	29.0	1.0	1.3	50.5	2.8	0.8
1990	105.5	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1991	100.0	64.5	45.0	<10.0	<10.0	<10.0	<10.0	<10.0	3.8	10.0
1992	66.8	10.9	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1993	171.5	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1994	175.5	<10.0	<10.0	<10.0	24.9	<10.0	<10.0	<10.0	<10.0	10.0
1995	71.0	2.1	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	10.0
1996	40.0	27.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-6 (Continued)

COAL REFUSE KCl-EXTRACTABLE Al (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
							30 to 45 cm[1]			
1987										
1988							<10.0	4.0	3.5	10.0
1989							ND[2]	ND	ND	ND
1990							1.5	7.0	6.0	10.0
1991							<10.0	<10.0	<10.0	10.0
1992							<10.0	7.0	2.5	10.0
1993							<10.0	<10.0	<10.0	10.0
1994							<10.0	23.5	<10.0	10.0
1995							<10.0	5.7	<10.0	10.0
1996							<10.0	19.0	<10.0	10.0
							<2.0	<2.0	<2.0	2.0
							45 to 60 cm[1]			
1987										
1988									16.5	32.5
1989									ND	ND
1990									258.0	10.0
1991									63.5	10.0
1992									14.5	10.0
1993									20.5	10.0
1994									<10.0	2.0
1995									<10.0	10.0
1996									<10.0	10.0
									<2.0	2.0

[1]Plots with missing data were not monitored at these depths.
[2]ND = No data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-7

COAL REFUSE KCl-EXTRACTABLE Ca (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
1988	23,724	11,799	11,904	8,739	9,869	6,579	3,839	10,604	6,534	7,614
1989	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1990	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1991	19,715	18,165	24,015	6,515	9,465	6,565	4,115	8,815	7,415	5,955
1992	15,287	13,482	7,877	4,277	6,522	4,892	3,532	4,727	4,977	5,318
1993	15,890	14,905	11,295	4,015	6,320	8,440	3,555	4,650	6,720	5,915
1994	16,443	9,188	10,523	4,013	10,018	7,288	3,403	5,843	5,882	7,547
1995	9,440	6,555	9,170	2,510	6,480	4,140	1,950	3,610	2,810	4,445
1996	15,181	13,201	5,657	3,026	3,908	2,155	1,406	2,534	2,611	4,801
					15 to 30 cm					
1987	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1988	17,754	17,539	23,849	11,829	11,904	16,114	17,474	12,129	15,804	16,544
1989	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1990	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1991	24,915	22,765	21,215	21,465	19,965	19,115	14,615	21,115	21,765	11,770
1992	17,512	10,972	16,262	13,207	12,532	15,767	5,857	11,302	8,892	10,733
1993	14,775	13,085	16,535	16,510	14,195	17,005	7,670	12,950	11,870	11,995
1994	20,213	17,458	18,258	5,453	4,763	10,743	5,108	16,433	12,752	16,337
1995	8,080	6,690	3,215	1,365	851	8,870	2,695	9,855	8,030	6,570
1996	16,266	2,707	18,591	16,456	17,156	19,706	2,521	13,066	6,991	9,926

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-7 (Continued)

COAL REFUSE KCl-EXTRACTABLE Ca (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	----------30 to 45 cm^2----------									
1987							ND	ND	ND	ND
1988							ND	ND	ND	ND
1989							ND	ND	ND	ND
1990							ND	ND	ND	ND
1991							22,615	24,265	22,515	12,645
1992							16,047	16,432	11,317	9,018
1993							15,130	15,505	12,035	15,860
1994							17,908	4,283	6,287	14,882
1995							9,450	2,880	8,840	7,880
1996							19,261	18,566	13,776	16,991
	----------45 to 60 cm^2----------									
1987									ND	ND
1988									ND	ND
1989									ND	ND
1990									ND	ND
1991									24,065	12,620
1992									14,717	10,298
1993									16,590	13,700
1994									20,047	14,152
1995									5,360	6,030
1996									14,931	13,861

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-8

COAL REFUSE KCl-EXTRACTABLE Mg (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
1988	40	830	234	241	383	362	316	723	624	454
1989	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1990	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1991	21	435	127	153	253	167	308	417	600	514
1992	14	209	129	104	144	162	184	340	311	262
1993	100	182	125	129	163	147	239	350	400	236
1994	22	198	100	152	164	114	168	192	227	137
1995	87	251	63	56	193	125	218	210	289	179
1996	20	415	155	138	295	188	188	430	397	337
					15 to 30 cm					
1987	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1988	42	545	445	177	670	308	530	708	536	315
1989	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1990	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1991	22	169	71	119	713	130	185	858	743	697
1992	7	113	151	41	245	78	113	316	518	274
1993	84	297	158	45	223	105	208	317	370	183
1994	9	105	26	80	49	70	70	143	210	131
1995	2	2	52	2	33	37	71	250	278	172
1996	16	24	356	83	583	127	73	186	304	390

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-8 (Continued)

COAL REFUSE KCl-EXTRACTABLE Mg (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm^2----------										
1987							ND	ND	ND	ND
1988							ND	ND	ND	ND
1989							ND	ND	ND	ND
1990							ND	ND	ND	ND
1991							505	596	667	787
1992							62	174	454	268
1993							114	160	434	106
1994							35	36	182	162
1995							126	12	216	173
1996							73	85	474	232
----------45 to 60 cm^2----------										
1987									ND	ND
1988									ND	ND
1989									ND	ND
1990									ND	ND
1991									190	518
1992									182	245
1993									227	177
1994									164	140
1995									36	372
1996									76	135

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-9

COAL REFUSE KCl-EXTRACTABLE Na (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
1988	19.0	40.5	34.0	29.5	34.0	32.5	23.0	41.5	26.5	15.5
1989	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1990	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1991	0.3	6.5	5.5	4.0	5.5	4.0	4.0	19.0	28.0	39.5
1992	457.3	376.3	211.3	85.8	235.3	353.3	32.8	56.3	61.3	19.9
1993	119.8	116.8	184.4	164.4	120.4	149.8	40.9	57.4	181.8	35.8
1994	74.1	43.2	43.1	49.8	50.4	82.6	72.1	70.9	81.3	50.0
1995	271.0	289.5	15.0	2.0	2.0	131.5	145.0	163.0	149.0	101.0
1996	217.0	278.0	259.0	107.0	96.0	83.0	97.0	75.0	22.0	38.0
	15 to 30 cm									
1987	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1988	17.5	24.0	26.5	25.0	23.0	14.5	17.0	6.5	21.5	7.0
1989	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1990	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1991	1.8	2.5	1.5	2.5	4.0	9.0	8.5	11.5	36.0	38.5
1992	436.3	257.8	233.8	255.8	243.8	58.3	25.3	58.8	95.3	20.9
1993	333.4	117.8	146.4	151.4	157.8	272.4	143.4	55.4	92.4	18.1
1994	56.1	42.0	53.1	44.9	42.5	72.1	64.1	76.6	74.9	43.0
1995	265.5	669.0	2.0	2.0	17.8	158.0	155.0	29.0	144.5	104.5
1996	309.0	347.0	120.0	128.0	68.0	90.0	94.0	50.0	37.0	49.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-9 (Continued)

COAL REFUSE KCl-EXTRACTABLE Na (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm^2----------										
1987							ND	ND	ND	ND
1988							ND	ND	ND	ND
1989							ND	ND	ND	ND
1990							ND	ND	ND	ND
1991							3.5	6.0	27.5	21.0
1992							48.6	33.6	28.2	21.6
1993							172.4	135.8	82.9	8.3
1994							66.9	51.8	54.9	44.9
1995							157.0	41.0	125.0	109.0
1996							83.0	57.0	17.0	40.0
----------45 to 60 cm^2----------										
1987									ND	ND
1988									ND	ND
1989									ND	ND
1990									ND	ND
1991									6.5	12.5
1992									16.3	8.4
1993									36.7	19.7
1994									45.3	53.6
1995									166.5	33.8
1996									23.0	66.0

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-10

COAL REFUSE KCl-EXTRACTABLE Fe (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	313.70	2.70	<2	<2	<2	1.05	2.05	0.60	2.50	<2
1988	319.00	6.00	9.00	5.50	5.30	<2	<2	<2	<2	0.20
1989	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
1990	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1991	166.00	<2	<2	<2	<2	<2	<2	<2	0.50	<2
1992	46.35	<2	<2	<2	<2	<2	<2	2.35	<2	<2
1993	159.00	<2	<2	<2	<2	<2	<2	<2	<2	<2
1994	279.50	1.60	<2	<2	<2	<2	<2	<2	<2	<2
1995	187.50	<2	<2	<2	<2	<2	<2	<2	<2	<2
1996	161.20	0.15	0.30	0.20	3.10	0.55	0.08	3.15	3.55	1.65
					15 to 30 cm					
1987	341.20	130.70	<2	<2	<2	1.25	1.10	4.25	1.00	<2
1988	295.50	17.00	9.00	11.50	16.00	5.50	0.20	0.20	0.20	3.00
1989	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1990	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1991	535.00	1.00	12.50	<2	<2	<2	<2	<2	0.50	<2
1992	33.65	<2	<2	<2	<2	<2	<2	3.20	6.75	<2
1993	193.50	<2	<2	<2	<2	<2	<2	<2	<2	<2
1994	579.00	<2	<2	<2	<2	<2	<2	<2	<2	<2
1995	92.20	<2	<2	<2	<2	<2	<2	<2	<2	<2
1996	181.30	105.20	0.25	ND	0.10	0.08	0.08	0.08	0.50	0.10

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-10 (Continued)

COAL REFUSE KCl-EXTRACTABLE Fe (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm^2----------										
1987							3.50	4.30	<2	0.65
1988							ND	ND	ND	ND
1989							ND	ND	ND	ND
1990							ND	ND	ND	ND
1991							<2	1.50	<2	14.50
1992							<2	<2	<2	<2
1993							<2	2.85	<2	<2
1994							<2	<2	<2	<2
1995							<2	4.00	<2	<2
1996							0.08	0.08	0.08	0.08
----------45 to 60 cm^2----------										
1987									11.55	20.25
1988									ND	ND
1989									ND	ND
1990									ND	ND
1991									<2	8.50
1992									<2	<2
1993									<2	<2
1994									<2	<2
1995									<2	<2
1996									0.08	0.10

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-11

COAL REFUSE WATER-EXTRACTABLE Al (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------0 to 15 cm----------										
1987	441.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
1988	421.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
1989	314.5	8.0	10.0	2.0	2.0	4.5	10.0	22.5	32.0	39.5
1990	408.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
1991	388.0	0.5	10.0	10.0	10.0	10.0	0.3	141.5	158.0	10.0
1992	214.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.1
1993	221.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
1994	444.0	0.0	1.0	5.0	5.0	1.0	1.0	1.0	0.8	1.0
1995	381.8	16.0	2.2	0.1	0.5	0.1	0.1	0.1	0.4	0.5
1996	207.8	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
----------15 to 30 cm----------										
1987	476.0	245.0	10.0	10.0	21.5	10.0	10.0	10.0	10.0	10.0
1988	400.0	24.0	10.0	10.0	46.0	10.0	10.0	8.9	10.0	10.0
1989	260.0	79.5	2.5	2.0	25.5	2.0	15.0	40.5	30.5	38.0
1990	362.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0.5
1991	390.0	119.0	77.5	10.0	1.0	10.0	41.0	38.5	2.7	10.0
1992	102.4	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
1993	304.5	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
1994	525.0	32.0	5.0	5.0	69.0	1.0	1.0	1.0	1.0	2.0
1995	224.1	40.5	0.5	0.1	0.1	0.1	0.1	0.1	1.4	1.5
1996	145.6	37.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-11 (Continued)

COAL REFUSE WATER-EXTRACTABLE Al (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							1.5	36.0	10.0	10.0
1988							ND[2]	ND	ND	ND
1989							17.0	27.5	36.5	10.0
1990							10.0	0.5	10.0	10.0
1991							22.5	30.0	0.3	10.0
1992							10.0	10.0	10.0	10.0
1993							10.0	10.0	12.2	10.0
1994							1.0	14.0	1.0	1.0
1995							0.1	23.1	6.3	1.4
1996							2.0	2.0	2.0	2.0
----------45 to 60 cm[1]----------										
1987									37.5	49.0
1988									ND	ND
1989									285.0	2.0
1990									63.0	10.0
1991									1.0	10.0
1992									17.9	10.0
1993									10.0	10.0
1994									5.0	2.0
1995									14.6	0.1
1996									6.0	2.0

[1]Plots with missing data were not monitored at these depths.
[2]ND = No data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-12

COAL REFUSE WATER-EXTRACTABLE Ca (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	5,975	6,160	6,315	5,560	4,705	5,635	3,405	6,605	5,755	6,005
1988	6,994	7,354	7,452	7,102	7,687	7,630	4,245	7,972	6,905	7,604
1989	7,940	8,565	9,615	5,805	7,415	9,220	5,115	8,875	7,955	9,415
1990	2,305	7,615	7,355	6,735	6,970	6,865	2,855	6,955	4,970	6,930
1991	6,203	7,808	8,278	7,328	7,173	4,888	405	5,728	4,623	3,160
1992	9,381	9,011	6,921	5,891	8,181	4,561	1,876	1,896	3,216	7,923
1993	6,314	6,254	6,774	3,519	5,049	6,579	543	1,504	1,639	6,631
1994	6,344	6,014	6,284	2,934	6,489	5,924	620	3,479	3,413	5,953
1995	6,144	5,444	5,640	2,521	4,103	4,619	1,016	2,958	899	2,881
1996	6,718	6,139	6,373	3,840	3,390	2,216	606	596	233	2,653
					15 to 30 cm					
1987	5,940	5,735	5,245	5,250	5,055	6,590	6,284	6,515	2,955	6,015
1988	6,958	6,430	6,766	7,409	6,687	7,842	7,033	7,799	7,815	7,435
1989	7,540	9,205	7,045	7,570	8,610	10,320	10,125	8,750	10,080	11,185
1990	2,160	7,190	6,910	7,590	7,050	7,345	7,080	6,590	7,250	7,450
1991	5,863	6,813	6,588	7,448	7,793	7,383	8,128	7,658	7,523	5,420
1992	8,986	9,136	9,076	9,591	8,866	9,391	8,221	8,411	7,801	9,598
1993	6,269	6,689	6,254	6,289	6,594	6,829	6,859	6,924	6,889	5,866
1994	6,399	6,549	6,594	5,789	6,634	6,214	5,089	5,939	5,803	6,138
1995	5,328	5,322	5,748	5,392	6,273	6,465	4,834	7,413	6,840	4,723
1996	6,219	6,200	5,760	6,693	4,832	6,601	4,163	6,378	3,978	6,565

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-12 (Continued)

COAL REFUSE WATER-EXTRACTABLE Ca (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
							30 to 45 cm[1]			
1987							6,325	6,400	6,065	6,140
1988							ND[2]	ND	ND	ND
1989							8,195	9,455	10,365	7,635
1990							7,750	6,925	6,925	8,730
1991							7,578	7,813	8,773	5,310
1992							8,961	9,031	9,196	8,918
1993							6,624	6,739	6,869	5,866
1994							6,334	5,904	6,043	6,113
1995							7,080	5,345	7,669	7,085
1996							6,901	6,464	5,799	6,728
							45 to 60 cm[1]			
1987									6,830	6,595
1988									ND	ND
1989									8,220	5,485
1990									5,835	8,380
1991									6,913	5,280
1992									8,891	8,806
1993									6,494	6,089
1994									6,238	5,913
1995									5,528	3,750
1996									6,682	6,831

[1]Plots with missing data were not monitored at these depths.
[2]ND = No data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-13

COAL REFUSE WATER-EXTRACTABLE Mg (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	337	1,150	660	481	568	650	542	1,155	932	859
1988	203	923	514	584	832	567	538	1,126	1,154	1,098
1989	145	515	343	331	554	370	279	663	759	1,075
1990	258	273	238	257	454	285	152	528	412	523
1991	148	506	205	253	362	198	58	421	532	435
1992	181	578	336	385	549	390	237	381	472	1,000
1993	136	238	192	165	215	298	91	263	278	276
1994	203	435	247	213	353	288	104	269	310	304
1995	365	334	181	190	274	345	116	371	218	255
1996	223	403	206	127	198	328	124	101	64	387
					15 to 30 cm					
1987	332	774	338	405	609	503	598	937	853	734
1988	215	847	629	652	1,057	761	770	874	1,085	976
1989	128	337	457	480	740	486	557	644	1,130	1,285
1990	156	382	360	288	681	368	346	757	784	591
1991	154	407	191	288	501	246	332	570	839	715
1992	189	514	490	350	886	451	379	641	1,244	1,090
1993	181	264	190	93	228	216	241	307	505	298
1994	216	327	163	164	282	252	221	340	412	321
1995	196	208	288	184	694	328	204	560	614	320
1996	200	175	189	97	313	459	148	290	264	486

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-13 (Continued)

COAL REFUSE WATER-EXTRACTABLE Mg (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							657	364	726	747
1988							ND[2]	ND	ND	ND
1989							485	541	1,002	839
1990							402	415	826	584
1991							417	567	659	559
1992							397	634	1,464	1,270
1993							203	280	643	160
1994							183	207	600	657
1995							385	243	855	696
1996							202	197	463	359
----------45 to 60 cm[1]----------										
1987									422	596
1988									ND	ND
1989									829	591
1990									683	582
1991									382	348
1992									1,019	1,009
1993									460	323
1994									516	544
1995									400	401
1996									301	295

[1]Plots with missing data were not monitored at these depths.
[2]ND = No data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-14

COAL REFUSE WATER-EXTRACTABLE Na (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	5.0	80.0	72.5	37.5	68.0	86.5	60.5	155.5	178.0	164.0
1988	8.0	43.0	28.0	29.0	38.0	48.0	46.0	109.0	133.0	122.0
1989	2.0	14.0	14.5	7.5	12.0	6.0	16.0	30.5	57.5	86.0
1990	1.5	8.0	5.0	1.5	3.0	1.5	10.0	43.0	32.0	32.0
1991	4.0	6.0	4.5	4.0	7.5	2.0	5.5	24.0	42.5	42.5
1992	1.3	2.0	1.0	2.0	2.0	2.0	9.9	40.9	48.5	54.4
1993	4.2	2.1	4.3	5.5	3.7	13.5	5.2	30.4	26.8	11.0
1994	23.0	22.0	20.0	10.0	12.0	12.0	8.0	16.0	28.0	23.0
1995	0.1	0.1	0.1	0.1	0.1	0.1	0.1	3.2	2.9	0.1
1996	2.1	4.4	2.6	2.0	2.0	19.9	16.7	5.4	11.4	33.2
	15 to 30 cm									
1987	4.0	17.0	24.5	9.5	21.0	26.5	53.5	95.5	180.5	170.5
1988	9.0	26.0	23.0	21.0	21.0	21.0	37.0	76.0	170.0	144.0
1989	1.5	3.5	8.0	3.5	2.0	2.0	20.5	16.5	77.0	129.0
1990	2.0	14.0	1.5	2.0	3.5	3.5	16.0	56.0	63.0	48.0
1991	3.0	2.5	2.0	4.5	2.0	5.0	10.5	26.5	81.0	75.0
1992	2.0	2.0	1.0	2.0	2.0	18.4	18.8	62.5	73.8	57.1
1993	2.8	4.9	6.2	4.3	5.0	10.7	12.3	36.5	49.4	25.8
1994	13.0	15.0	12.0	11.0	25.0	11.0	12.0	24.0	50.0	35.0
1995	0.1	0.1	0.1	0.1	0.1	0.1	2.0	11.1	10.2	0.1
1996	29.0	25.0	32.5	2.0	20.0	22.8	15.2	6.8	22.6	54.8

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-14 (Continued)

COAL REFUSE WATER-EXTRACTABLE Na (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							17.0	24.5	66.5	75.5
1988							ND[2]	ND	ND	ND
1989							11.5	9.0	52.0	144.5
1990							7.0	22.0	69.0	40.0
1991							6.5	15.0	57.5	71.0
1992							12.7	30.7	82.9	89.9
1993							9.5	11.1	79.3	39.4
1994							8.0	20.0	49.0	84.0
1995							0.1	0.1	0.1	9.2
1996							5.4	6.5	24.0	24.8
----------45 to 60 cm[1]----------										
1987									14.0	27.0
1988									0.0	0.0
1989									5.0	87.0
1990									27.0	45.0
1991									24.5	55.0
1992									55.8	93.0
1993									51.7	28.0
1994									36.0	102.0
1995									0.1	18.5
1996									14.9	27.9

[1]Plots with missing data were not monitored at these depths.
[2]ND = No data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-15

COAL REFUSE WATER-EXTRACTABLE K (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	4.5	113.0	117.0	69.0	144.0	187.0	119.0	241.5	296.0	261.5
1988	6.0	76.0	77.0	69.0	107.0	157.0	203.0	145.0	220.0	211.0
1989	6.0	61.5	76.5	68.5	92.5	142.0	108.5	110.5	121.0	151.5
1990	4.0	73.0	67.0	72.0	71.0	102.0	341.0	134.0	114.0	82.0
1991	5.5	51.5	48.0	72.0	103.5	113.5	98.5	150.0	166.5	120.0
1992	2.0	22.3	33.5	33.9	37.4	47.7	175.0	208.0	102.8	193.0
1993	15.0	23.5	55.6	39.6	44.1	85.3	56.1	116.0	69.9	59.3
1994	13.0	79.0	81.0	78.0	55.0	97.0	80.0	64.0	77.0	71.0
1995	0.1	12.3	36.7	28.7	50.5	85.8	63.1	91.2	84.4	33.4
1996	30.7	20.0	29.4	20.4	23.7	161.2	144.6	50.0	86.5	150.0
	15 to 30 cm									
1987	5.0	10.0	29.5	17.5	33.5	46.0	80.5	129.0	297.0	268.0
1988	6.0	38.0	25.0	30.0	31.0	26.0	63.0	107.0	266.0	227.0
1989	12.0	26.5	30.5	30.5	25.5	32.5	59.0	47.0	108.5	193.0
1990	5.0	34.0	31.0	18.0	18.0	20.0	137.0	81.0	61.0	44.0
1991	7.0	33.0	32.5	26.5	25.0	35.0	49.5	47.0	103.0	97.5
1992	105.0	2.0	9.8	7.0	86.5	38.5	75.9	81.7	127.1	83.3
1993	2.0	12.3	21.5	5.5	3.0	17.2	44.5	49.5	74.1	28.0
1994	2.0	42.0	32.0	29.0	30.0	35.0	44.0	43.0	73.0	49.0
1995	2.0	45.6	21.1	13.7	40.0	37.3	45.7	41.0	42.6	5.6
1996	6.0	6.0	9.7	7.1	3.1	45.8	66.5	17.5	56.5	79.7

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-15 (Continued)

COAL REFUSE WATER-EXTRACTABLE K (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							25.5	25.5	80.5	134.0
1988							ND[2]	ND	ND	ND
1989							51.5	76.0	81.5	252.0
1990							87.0	24.0	79.0	76.0
1991							31.0	38.5	70.0	108.0
1992							45.7	64.8	101.8	154.0
1993							21.1	33.2	83.4	2.2
1994							26.0	35.0	65.0	107.0
1995							28.5	23.1	4.6	17.4
1996							29.0	6.0	57.6	18.7
----------45 to 60 cm[1]----------										
1987									16.5	32.0
1988									ND	ND
1989									19.0	145.5
1990									13.0	88.0
1991									29.0	92.0
1992									56.6	156.5
1993									48.0	60.6
1994									45.0	151.0
1995									21.5	33.9
1996									28.7	50.1

[1]Plots with missing data were not monitored at these depths.
[2]ND = No data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-16

COAL REFUSE WATER-EXTRACTABLE Fe (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	620.00	5.00	4.00	4.00	5.50	2.00	2.00	4.50	3.00	2.50
1988	739.00	3.00	2.00	2.00	1.00	1.00	2.00	2.00	2.00	2.00
1989	398.00	1.00	2.00	2.00	0.50	1.00	2.00	2.00	2.00	2.00
1990	701.00	3.00	2.00	2.00	2.00	2.00	2.00	1.00	0.50	41.00
1991	537.50	4.00	2.00	1.00	2.00	2.00	1.00	1.00	1.00	3.50
1992	300.00	5.45	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
1993	241.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
1994	1,045.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
1995	912.50	31.45	0.95	0.50	2.00	1.05	1.25	9.45	1.50	0.10
1996	680.30	0.40	0.65	0.50	0.45	0.10	0.30	0.90	0.55	0.20
	15 to 30 cm									
1987	816.50	132.00	4.00	5.00	41.50	2.00	2.00	3.50	2.50	2.00
1988	864.00	6.00	3.00	2.00	23.00	1.00	2.00	4.00	2.00	1.00
1989	323.00	23.50	2.00	2.00	3.00	2.00	2.00	2.50	2.00	2.00
1990	938.00	4.00	2.00	2.00	0.50	2.00	2.00	1.00	1.00	46.00
1991	787.50	10.50	21.00	2.00	2.00	2.50	1.00	3.00	1.00	4.50
1992	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
1993	847.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
1994	909.00	3.00	2.00	2.00	27.00	2.00	2.00	2.00	2.00	2.00
1995	413.00	7.45	0.60	0.30	0.10	0.80	0.10	1.40	0.10	0.10
1996	573.00	0.08	1.20	0.15	0.20	0.05	0.08	0.08	0.25	0.15

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-16 (Continued)

COAL REFUSE WATER-EXTRACTABLE Fe (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							2.50	9.50	11.00	1.50
1988							ND[1]	ND	ND	ND
1989							2.00	2.00	2.00	2.00
1990							1.00	39.00	1.00	2.00
1991							2.00	9.50	2.50	6.00
1992							2.00	2.00	2.00	2.00
1993							2.00	2.00	2.00	2.00
1994							2.00	2.00	2.00	2.00
1995							0.65	4.40	0.10	0.10
1996							0.08	0.35	0.15	0.20
----------45 to 60 cm[1]----------										
1987									3.00	117.50
1988									ND	ND
1989									92.00	2.00
1990									113.00	2.00
1991									1.00	4.50
1992									1.10	2.00
1993									2.00	2.00
1994									2.00	2.00
1995									0.10	0.10
1996									0.20	0.08

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-17

COAL REFUSE HCl-EXTRACTABLE Cd (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
0 to 15 cm										
1987	5.97	46.90	41.20	25.40	49.90	49.30	40.30	79.10	84.00	79.90
1988	6.39	45.40	43.00	32.10	48.20	55.00	34.90	81.10	86.10	118.00
1989	3.22	29.40	37.20	21.90	44.60	49.80	44.60	70.10	105.00	98.40
1990	3.00	50.00	42.00	31.00	52.00	44.00	52.00	85.00	87.00	76.00
1991	<2.00	18.00	18.00	28.00	51.00	43.00	39.00	83.00	92.00	113.00
1992	<1.00	14.00	39.00	13.00	45.00	39.00	34.00	57.00	47.00	101.00
1993	<2.00	20.00	30.00	23.00	40.00	37.00	50.00	109.00	105.00	79.00
1994	<1.00	48.00	36.00	30.00	42.00	44.00	25.00	64.00	78.00	58.00
1995	<2.00	32.00	36.00	42.00	55.00	45.00	35.00	66.00	41.00	10.00
1996	<2.00	42.00	33.00	34.00	79.00	36.00	14.00	70.00	77.00	77.00
15 to 30 cm										
1987	6.09	10.20	7.63	9.46	21.30	14.60	23.30	30.80	66.40	64.50
1988	8.57	15.20	16.10	7.54	22.60	17.30	23.70	17.50	56.50	63.50
1989	3.05	3.61	7.42	6.03	12.50	8.96	20.70	14.20	59.90	68.20
1990	3.00	21.00	9.00	8.00	15.00	16.00	30.00	37.00	56.00	36.00
1991	<2.00	<2.00	<1.00	6.00	20.00	10.00	29.00	24.00	60.00	56.00
1992	<1.00	3.00	5.00	<2.00	17.00	15.00	23.00	42.00	56.00	77.00
1993	<2.00	<1.00	4.00	<2.00	6.00	6.00	24.00	45.00	62.00	36.00
1994	<2.00	12.00	4.00	27.00	3.00	24.00	18.00	28.00	61.00	30.00
1995	<2.00	4.00	4.00	7.00	19.00	5.00	22.00	29.00	84.00	80.00
1996	3.00	5.00	5.00	3.00	13.00	8.00	8.00	34.00	67.00	53.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-17 (Continued)

COAL REFUSE HCl-EXTRACTABLE Cd (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							10.10	7.91	25.40	40.30
1988							5.97	10.90	15.70	23.00
1989							19.90	22.70	32.10	43.40
1990							9.00	10.00	32.00	18.00
1991							10.00	8.00	14.00	36.00
1992							9.00	3.00	23.00	55.00
1993							22.00	7.00	39.00	17.00
1994							13.00	<2.00	33.00	29.00
1995							10.00	8.00	53.00	32.00
1996							3.00	4.00	19.00	17.00
----------45 to 60 cm[1]----------										
1987									6.61	11.90
1988									6.17	12.20
1989									11.10	31.10
1990									12.00	14.00
1991									4.00	23.00
1992									6.00	35.00
1993									16.00	11.00
1994									6.00	25.00
1995									16.00	17.00
1996									6.00	15.00

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-18

COAL REFUSE HCl-EXTRACTABLE Cr (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	8.08	267.00	42.80	52.50	122.00	58.90	38.20	39.90	123.00	228.00
1988	3.61	424.00	88.30	68.10	408.00	96.10	386.00	261.00	174.00	186.00
1989	1.93	120.00	40.10	49.70	147.00	18.10	53.00	136.00	166.00	146.00
1990	2.00	162.00	56.00	33,00	104.00	46.00	53.00	137.00	120.00	169.00
1991	2.00	71.00	64.00	50.00	120.00	10.00	62.00	188.00	185.00	202.00
1992	<1.00	12.00	12.00	2.00	27.00	26.00	29.00	69.00	52.00	22.00
1993	<1.00	81.00	79.00	41.00	96.00	33.00	50.00	119.00	116.00	159.00
1994	<1.00	113.00	61.00	43.00	114.00	41.00	32.00	119.00	120.00	99.00
1995	<1.00	77.00	36.00	50.00	90.00	63.00	50.00	94.00	94.00	30.00
1996	<1.00	122.00	35.00	37.00	117.00	8.00	27.00	167.00	122.00	123.00
					15 to 30 cm					
1987	5.12	34.90	19.40	21.70	60.70	39.10	205.00	225.00	22.80	239.00
1988	3.56	65.40	58.10	67.00	328.00	76.20	85.70	121.00	242.00	258.00
1989	1.93	8.70	26.90	9.29	51.40	26.40	53.90	40.00	202.00	179.00
1990	<1.00	59.00	26.00	11.00	58.00	58.00	43.00	237.00	221.00	236.00
1991	3.00	7.00	3.00	15.00	101.00	29.00	20.00	98.00	208.00	203.00
1992	<1.00	3.00	6.00	<1.00	26.00	11.00	19.00	50.00	21.00	56.00
1993	<1.00	<1.00	13.00	3.00	25.00	11.00	26.00	68.00	211.00	143.00
1994	<1.00	36.00	9.00	57.00	10.00	27.00	31.00	101.00	140.00	95.00
1995	<1.00	9.00	11.00	12.00	69.00	16.00	28.00	122.00	106.00	156.00
1996	<1.00	15.00	12.00	4.00	63.00	31.00	14.00	152.00	157.00	129.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-18 (Continued)

COAL REFUSE HCl-EXTRACTABLE Cr (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							192.00	256.00	128.00	190.00
1988							12.90	10.80	89.50	110.00
1989							81.70	108.00	158.00	221.00
1990							18.00	30.00	188.00	86.00
1991							33.00	36.00	66.00	182.00
1992							8.00	6.00	28.00	47.00
1993							28.00	12.00	145.00	87.00
1994							30.00	7.00	96.00	113.00
1995							36.00	16.00	150.00	89.00
1996							14.00	16.00	88.00	61.00
----------45 to 60 cm[1]----------										
1987									22.40	48.50
1988									3.90	65.60
1989									34.50	165.00
1990									38.00	62.00
1991									11.00	118.00
1992									11.00	53.00
1993									80.00	68.00
1994									18.00	103.00
1995									46.00	40.00
1996									24.00	50.00

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-19

COAL REFUSE HCl-EXTRACTABLE Cu (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	9.1	236.0	159.0	131.0	286.0	82.6	230.0	486.0	509.0	357.0
1988	4.1	216.0	118.0	62.6	330.0	99.1	197.0	512.0	582.0	478.0
1989	3.5	181.0	154.0	118.0	244.0	164.0	207.0	356.0	395.0	451.0
1990	5.0	278.0	195.0	127.0	293.0	230.0	271.0	503.0	560.0	460.0
1991	4.0	137.0	113.0	151.0	328.0	138.0	224.0	443.0	445.0	511.0
1992	1.0	63.0	154.0	41.0	242.0	130.0	140.0	220.0	138.0	438.0
1993	3.0	113.0	129.0	118.0	187.0	583.0	320.0	700.0	583.0	493.0
1994	2.0	213.0	169.0	134.0	223.0	225.0	129.0	412.0	457.0	287.0
1995	2.0	125.0	101.0	135.0	182.0	285.0	183.0	326.0	236.0	401.0
1996	3.0	151.0	67.0	85.0	217.0	103.0	81.0	636.0	509.0	294.0
					15 to 30 cm					
1987	8.5	41.9	30.9	23.7	117.0	66.1	114.0	191.0	375.0	282.0
1988	3.4	41.0	44.3	35.6	135.0	86.1	109.0	112.0	366.0	279.0
1989	3.5	6.7	28.9	11.2	54.6	30.5	84.8	59.7	247.0	341.0
1990	4.0	122.0	44.0	24.0	91.0	109.0	144.0	240.0	394.0	231.0
1991	7.0	12.0	6.0	29.0	130.0	51.0	123.0	141.0	323.0	315.0
1992	0.0	5.0	24.0	4.0	95.0	67.0	101.0	230.0	214.0	450.0
1993	1.0	5.0	19.0	6.0	31.0	36.0	146.0	348.0	403.0	237.0
1994	2.0	64.0	15.0	137.0	12.0	124.0	94.0	176.0	348.0	187.0
1995	2.0	16.0	13.0	17.0	118.0	29.0	114.0	176.0	335.0	166.0
1996	3.0	14.0	15.0	7.0	88.0	56.0	39.0	369.0	438.0	207.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-19 (Continued)

COAL REFUSE HCl-EXTRACTABLE Cu (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
30 to 45 cm[1]										
1987							45.5	48.1	128.0	195.0
1988							13.8	11.8	81.8	159.0
1989							80.8	89.2	174.0	234.0
1990							23.0	32.0	205.0	95.0
1991							52.0	46.0	73.0	228.0
1992							48.0	19.0	130.0	288.0
1993							142.0	47.0	224.0	110.0
1994							66.0	9.0	175.0	164.0
1995							56.0	50.0	94.0	62.0
1996							15.0	25.0	133.0	85.0
45 to 60 cm[1]										
1987									17.9	49.9
1988									5.2	101.0
1989									45.9	162.0
1990									47.0	78.0
1991									17.0	144.0
1992									30.0	198.0
1993									100.0	78.0
1994									26.0	133.0
1995									54.0	83.0
1996									31.0	78.0

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-20

COAL REFUSE HCl-EXTRACTABLE Ni (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	8.7	82.9	55.9	40.7	80.2	66.6	58.5	114.0	123.0	105.0
1988	11.5	107.0	82.7	52.1	37.7	44.1	48.2	115.0	116.0	116.0
1989	8.0	45.6	45.0	31.2	54.7	56.4	58.9	82.8	109.0	135.0
1990	6.0	63.0	41.0	31.0	57.0	41.0	69.0	126.0	130.0	117.0
1991	7.0	29.0	24.0	30.0	52.0	40.0	34.0	99.0	107.0	108.0
1992	7.0	16.0	32.0	8.0	37.0	26.0	29.0	69.0	52.0	127.0
1993	7.0	25.0	37.0	26.0	42.0	33.0	50.0	119.0	116.0	92.0
1994	7.0	42.0	24.0	13.0	27.0	20.0	10.0	57.0	70.0	48.0
1995	2.0	10.0	10.0	44.0	48.0	16.0	46.0	10.0	70.0	10.0
1996	7.0	47.0	23.0	22.0	53.0	29.0	14.0	88.0	89.0	73.0
	15 to 30 cm									
1987	11.2	18.2	13.0	10.8	36.3	25.6	37.1	56.8	107.0	88.8
1988	21.0	61.6	52.0	26.2	61.7	46.6	36.3	28.4	85.9	74.5
1989	10.3	10.2	14.4	11.1	17.2	18.6	33.0	23.3	85.2	109.0
1990	6.0	31.0	15.0	12.0	21.0	25.0	46.0	62.0	91.0	66.0
1991	7.0	7.0	7.0	11.0	22.0	15.0	26.0	36.0	86.0	80.0
1992	7.0	7.0	7.0	7.0	16.0	11.0	19.0	50.0	72.0	102.0
1993	7.0	7.0	8.0	7.0	8.0	11.0	26.0	68.0	85.0	49.0
1994	7.0	7.0	7.0	15.0	7.0	7.0	7.0	25.0	61.0	27.0
1995	1.0	1.0	5.0	8.0	28.0	5.0	18.0	19.0	24.0	13.0
1996	7.0	4.0	5.0	7.0	16.0	6.0	8.0	53.0	86.0	59.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-20 (Continued)

COAL REFUSE HCl-EXTRACTABLE Ni (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							15.9	17.3	45.2	63.8
1988							11.6	11.6	27.2	42.4
1989							32.7	35.6	61.0	76.5
1990							15.0	14.0	56.0	34.0
1991							15.0	17.0	26.0	53.0
1992							8.0	7.0	30.0	77.0
1993							28.0	12.0	49.0	27.0
1994							7.0	7.0	31.0	32.0
1995							12.0	5.0	18.0	28.0
1996							7.0	8.0	33.0	22.0
----------45 to 60 cm[1]----------										
1987									13.5	23.3
1988									9.8	26.0
1989									26.2	55.1
1990									20.0	30.0
1991									10.0	32.0
1992									7.0	54.0
1993									24.0	24.0
1994									7.0	26.0
1995									17.0	19.0
1996									12.0	20.0

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-21

COAL REFUSE HCl-EXTRACTABLE Pb (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
0 to 15 cm										
1987	1.13	31.80	14.40	42.10	41.90	15.70	35.90	13.30	7.98	26.00
1988	4.31	49.80	15.10	17.90	48.70	17.50	51.60	21.10	10.90	12.40
1989	0.32	25.90	2.59	33.20	49.30	29.10	28.50	24.00	8.53	11.80
1990	<1.00	31.00	21.00	38.00	65.00	23.00	30.00	13.00	11.00	18.00
1991	<1.00	21.00	10.00	18.00	21.00	<1.00	62.00	20.00	16.00	15.00
1992	<1.00	<1.00	<1.00	<1.00	2.00	<1.00	<1.00	<1.00	<1.00	<1.00
1993	<1.00	47.00	15.00	33.00	40.00	10.00	61.00	7.00	10.00	5.00
1994	50.00	13.00	13.00	53.00	42.00	12.00	39.00	15.00	10.00	11.00
1995	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996	7.00	35.00	10.00	33.00	71.00	7.00	31.00	22.00	17.00	18.00
15 to 30 cm										
1987	2.24	26.80	5.81	19.40	46.70	23.50	14.20	31.60	13.00	30.40
1988	0.97	39.20	19.70	47.00	60.10	14.10	20.70	25.00	29.80	26.90
1989	0.32	0.49	8.52	3.25	17.70	15.80	27.40	17.10	19.60	16.80
1990	<1.00	37.00	16.00	12.00	44.00	38.00	26.00	34.00	24.00	45.00
1991	4.00	<1.00	<1.00	7.00	22.00	8.00	13.00	34.00	21.00	29.00
1992	<1.00	<1.00	3.00	<1.00	11.00	6.00	<1.00	<1.00	<1.00	<1.00
1993	<1.00	<1.00	8.00	4.00	14.00	16.00	38.00	31.00	33.00	24.00
1994	82.00	8.00	18.00	48.00	4.00	17.00	30.00	25.00	18.00	24.00
1995	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996	7.00	3.00	11.00	3.00	32.00	14.00	14.00	26.00	14.00	33.00

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-21 (Continued)

COAL REFUSE HCl-EXTRACTABLE Pb (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm^2----------										
1987							11.80	7.42	39.80	52.50
1988							8.79	2.15	22.80	37.80
1989							28.30	20.40	37.50	58.90
1990							7.00	12.00	40.00	43.00
1991							25.00	14.00	17.00	49.00
1992							4.00	2.00	<1.00	<1.00
1993							23.00	12.00	25.00	26.00
1994							23.00	<1.00	20.00	18.00
1995							ND	ND	ND	ND
1996							5.00	2.00	25.00	39.00
----------45 to 60 cm^2----------										
1987									12.70	30.60
1988									11.40	27.30
1989									18.00	82.60
1990									9.00	38.00
1991									23.00	47.00
1992									3.00	5.00
1993									20.00	23.00
1994									9.00	34.00
1995									ND	ND
1996									12.00	60.00

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-22

COAL REFUSE HCl-EXTRACTABLE Zn (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
0 to 15 cm										
1987	105	351	270	199	411	390	259	585	678	515
1988	202	589	544	560	543	7	703	1,302	1,552	1,305
1989	147	513	676	459	973	884	804	1,219	22	1,672
1990	208	780	657	602	955	740	910	1,590	295	1,175
1991	130	382	351	496	1,011	771	683	1,523	1,772	1,725
1992	59	276	763	263	926	756	654	1,109	884	2,023
1993	153	361	591	471	851	753	952	1,932	1,957	1,500
1994	165	960	700	647	848	805	452	1,117	1,548	988
1995	190	523	578	710	1,073	990	653	1,100	693	201
1996	205	628	482	535	1,336	729	270	1,568	1,515	1,257
15 to 30 cm										
1987	112	127	78	107	229	144	137	263	546	373
1988	228	163	228	220	6	6	280	310	1,031	761
1989	145	61	184	137	305	285	393	333	13	1,197
1990	215	335	252	165	393	443	578	672	615	642
1991	124	65	27	117	402	177	548	440	1,170	1,063
1992	68	35	124	71	388	333	481	803	1,117	1,527
1993	231	47	100	62	145	193	465	770	1,178	670
1994	190	287	89	550	168	465	340	497	1,095	565
1995	133	76	127	138	474	157	462	520	1,638	1,493
1996	213	99	77	62	333	222	147	803	1,361	831

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-22 (Continued)

COAL REFUSE HCl-EXTRACTABLE Zn (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							101	117	181	298
1988							209	300	292	544
1989							387	469	654	877
1990							242	212	668	482
1991							237	178	269	773
1992							234	116	447	1,210
1993							385	130	707	337
1994							284	45	598	567
1995							225	174	1,059	546
1996							55	111	388	329
----------45 to 60 cm[1]----------										
1987									65	90
1988									148	533
1989									339	659
1990									342	390
1991									113	555
1992									171	773
1993									339	249
1994									133	520
1995									325	288
1996									165	364

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-23

COAL REFUSE HCl-EXTRACTABLE Al (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	777	3,160	1,432	1,574	2,397	347	2,145	3,080	3,205	3,558
1988	562	1,951	1,321	1,613	3,092	419	1,719	4,263	3,591	3,272
1989	584	2,262	1,667	1,604	2,834	1,174	2,092	2,644	4,075	3,804
1990	735	3,062	1,758	1,272	2,848	1,506	2,150	3,588	3,603	4,180
1991	650	2,200	1,783	1,850	3,467	817	1,718	3,368	3,735	3,502
1992	359	671	519	284	798	394	516	716	579	583
1993	450	1,567	1,555	1,495	2,355	1,465	1,833	3,783	3,700	3,583
1994	563	2,387	1,497	1,520	2,035	1,323	1,152	2,658	2,853	2,358
1995	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
					15 to 30 cm					
1987	881	1,092	495	776	1,564	1,283	1,434	2,069	2,895	3,129
1988	500	732	686	746	1,717	8	756	1,419	3,121	2,366
1989	516	445	634	565	1,092	818	1,590	2,404	3,272	3,534
1990	707	1,478	800	637	1,195	1,347	1,752	2,380	3,285	2,665
1991	583	700	483	833	2,050	900	952	1,518	3,068	3,035
1992	335	251	274	172	533	446	454	1,116	1,045	950
1993	605	435	353	332	527	540	1,442	2,110	3,018	2,013
1994	658	807	358	1,432	352	862	992	1,438	2,615	1,537
1995	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-23 (Continued)

COAL REFUSE HCl-EXTRACTABLE Al (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	----------30 to 45 cm^2----------									
1987							968	825	1,550	2,363
1988							665	1,096	1,028	1,514
1989							1,376	1,816	2,268	2,752
1990							920	902	5,515	1,237
1991							718	702	1,118	2,330
1992							446	359	882	733
1993							1,075	558	2,120	1,118
1994							748	210	1,672	1,485
1995							ND	ND	ND	ND
1996							ND	ND	ND	ND
	----------45 to 60 cm^2----------									
1987										
1988									748	1,234
1989									521	1,244
1990									1,278	2,597
1991									1,052	1,097
1992									668	1,645
1993									340	713
1994									1,900	878
1995									442	1,448
1996									ND	ND
									ND	ND

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-24

COAL REFUSE HCl-EXTRACTABLE Fe (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	4,848	4,947	1,275	2,156	2,402	712	1,818	2,883	3,479	3,443
1988	3,958	5,941	1,695	2,153	4,299	1,812	1,729	3,511	1,633	1,733
1989	2,866	4,015	720	1,572	3,380	682	1,112	3,075	1,897	1,859
1990	4,267	4,067	1,633	1,522	2,848	1,415	1,178	1,740	1,375	2,120
1991	1,057	842	470	292	385	130	282	537	430	422
1992	1,736	769	334	244	443	307	244	274	144	165
1993	2,243	2,597	1,808	1,378	2,197	991	1,506	1,878	1,583	1,979
1994	3,650	2,210	1,388	1,203	2,478	893	932	1,603	1,593	1,355
1995	7	33	28	34	51	41	34	72	49	14
1996	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
					15 to 30 cm					
1987	5,093	4,062	1,568	3,963	4,684	3,407	2,033	4,800	5,687	4,489
1988	5,396	3,737	2,415	3,054	7,808	4,203	3,601	4,003	4,542	5,947
1989	2,741	1,894	2,106	1,452	2,858	2,824	2,445	3,863	4,373	3,567
1990	4,117	3,080	2,998	1,930	3,117	3,240	1,443	5,185	3,850	5,495
1991	1,515	500	710	285	1,453	642	167	895	1,318	1,203
1992	1,884	578	581	489	776	611	338	431	328	428
1993	2,867	1,020	1,247	1,023	1,713	2,251	1,544	4,799	4,866	3,549
1994	4,317	1,893	1,340	1,770	1,603	982	1,178	2,583	2,453	2,503
1995	7	8	7	8	22	9	23	45	98	80
1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-24 (Continued)

COAL REFUSE HCl-EXTRACTABLE Fe (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	----------30 to 45 cm^2----------									
1987							3,501	3,505	3,846	4,582
1988							3,338	3,104	3,750	14,000
1989							3,593	3,906	4,748	5,861
1990							4,020	4,180	5,515	4,345
1991							687	623	628	1,852
1992							758	716	820	895
1993							3,766	2,363	3,649	2,911
1994							1,608	845	2,713	3,033
1995							11	11	72	35
1996							ND	ND	ND	ND
	----------45 to 60 cm^2----------									
1987										
1988									2,402	3,009
1989									2,521	9,706
1990									3,509	5,153
1991									4,725	3,755
1992									392	1,448
1993									673	1,243
1994									3,129	3,121
1995									1,090	3,727
1996									22	22
									ND	ND

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-25

COAL REFUSE HCl-EXTRACTABLE Mn (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	82.6	266.0	296.0	362.0	423.0	352.0	372.0	289.0	389.0	326.0
1988	50.8	211.0	290.0	293.0	567.0	386.0	442.0	317.0	425.0	521.0
1989	29.3	114.0	237.0	306.0	293.0	286.0	348.0	220.0	359.0	372.0
1990	42.0	226.0	256.0	307.0	326.0	249.0	398.0	286.0	376.0	430.0
1991	23.0	98.0	167.0	269.0	226.0	175.0	293.0	261.0	309.0	311.0
1992	16.0	51.0	135.0	181.0	222.0	144.0	252.0	196.0	151.0	450.0
1993	23.0	107.0	202.0	350.0	268.0	307.0	488.0	377.0	418.0	298.0
1994	31.0	168.0	204.0	283.0	231.0	199.0	260.0	190.0	243.0	237.0
1995	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
					15 to 30 cm					
1987	107.0	125.0	78.0	287.0	204.0	186.0	263.0	159.0	386.0	274.0
1988	64.7	131.0	132.0	346.0	225.0	239.0	347.0	101.0	378.0	377.0
1989	24.1	28.7	84.8	284.0	91.7	153.0	303.0	76.3	352.0	310.0
1990	48.0	101.0	71.0	245.0	115.0	143.0	389.0	156.0	262.0	211.0
1991	23.0	37.0	26.0	172.0	99.0	88.0	254.0	104.0	283.0	223.0
1992	14.0	21.0	54.0	220.0	101.0	107.0	229.0	171.0	269.0	503.0
1993	32.0	114.0	42.0	157.0	39.0	119.0	360.0	205.0	357.0	174.0
1994	27.0	62.0	94.0	238.0	37.0	173.0	237.0	113.0	238.0	161.0
1995	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-25 (Continued)

COAL REFUSE HCl-EXTRACTABLE Mn (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm^2----------										
1987							131.0	88.6	168.0	213.0
1988							222.0	419.0	135.0	234.0
1989							260.0	235.0	217.0	228.0
1990							87.0	85.0	163.0	216.0
1991							95.0	46.0	119.0	204.0
1992							120.0	43.0	138.0	637.0
1993							178.0	46.0	182.0	106.0
1994							152.0	12.0	192.0	184.0
1995							ND	ND	ND	ND
1996							ND	ND	ND	ND
----------45 to 60 cm^2----------										
1987									65.0	110.0
1988									125.0	208.0
1989									95.9	182.0
1990									73.0	180.0
1991									155.0	222.0
1992									63.0	440.0
1993									125.0	88.0
1994									35.0	163.0
1995									ND	ND
1996									ND	ND

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-26

COAL REFUSE KCl-EXTRACTABLE NH_3-N (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	36.4	118.0	115.0	22.0	34.2	29.0	19.5	36.0	818.0	112.0
1988	4.9	17.6	8.6	6.8	13.6	7.3	8.6	24.9	41.5	30.6
1989	9.8	29.4	14.7	8.1	16.0	15.7	10.7	16.1	20.7	25.8
1990	7.7	19.5	8.9	6.9	8.9	10.6	25.1	36.6	47.4	29.2
1991	18.8	18.6	8.7	11.7	10.9	12.3	9.9	13.0	16.7	22.6
1992	11.2	10.1	4.5	3.0	5.7	7.4	3.9	35.3	7.1	7.4
1993	11.0	26.0	9.0	3.0	4.5	5.5	4.0	10.5	11.0	11.0
1994	1.5	2.2	0.3	0.5	1.7	1.7	0.2	1.5	2.7	1.9
1995	8.1	24.2	11.8	17.6	24.1	22.4	21.6	34.9	35.4	30.8
1996	11.3	19.2	5.6	7.9	9.0	5.9	3.9	7.6	8.0	8.8
1997	15.3	29.7	11.2	29.2	28.9	27.8	27.7	26.3	18.6	17.8
1998	7.7	14.5	7.8	2.9	8.6	7.8	3.7	8.8	3.2	12.0
1999	7.6	21.4	14.4	16.0	7.5	16.9	13.5	6.4	9.2	7.0
2000	11.3	10.5	3.5	0.2	5.6	4.1	0.9	7.9	12.2	16.5

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-26 (Continued)

COAL REFUSE KCl-EXTRACTABLE NH_3-N (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	15 to 30 cm									
1987	27.9	115.0	115.0	27.2	45.9	35.6	43.2	93.7	2682.0	2068.0
1988	10.4	22.2	15.1	9.4	13.2	8.9	17.8	78.2	286.0	306.0
1989	10.1	28.4	24.3	6.5	12.4	9.6	10.4	16.7	9.5	31.1
1990	7.7	15.5	9.7	5.1	9.7	7.6	11.7	76.9	45.8	69.2
1991	22.9	23.1	15.3	10.0	24.1	9.5	9.7	19.2	83.6	114.6
1992	14.6	15.6	7.1	5.7	8.1	6.6	4.6	11.5	12.4	13.1
1993	10.0	15.0	12.5	6.5	9.5	7.5	6.0	13.0	23.0	53.0
1994	1.7	2.6	1.1	1.7	1.4	1.1	0.4	1.6	2.2	1.8
1995	8.5	14.6	7.3	4.7	10.8	6.5	8.1	12.3	23.1	14.3
1996	10.6	13.9	11.3	6.4	11.3	7.8	3.3	12.2	12.1	10.9
1997	26.9	34.3	27.0	29.6	15.4	29.5	15.9	27.9	24.4	22.5
1998	5.2	9.7	12.4	5.5	8.2	6.7	4.7	12.0	6.7	9.7
1999	22.9	20.1	21.5	6.2	20.5	18.3	5.7	21.7	5.5	8.8
2000	5.3	13.4	7.4	3.0	8.5	11.1	3.4	7.0	12.7	13.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-26 (Continued)

COAL REFUSE KCl-EXTRACTABLE NH_3-N (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	30 to 45 cm[1]									
1987							50.0	23.8	93.9	101.0
1988							16.5	32.4	186.0	232.0
1989							9.8	15.8	25.2	148.0
1990							9.9	102.1	204.0	29.5
1991							13.1	25.3	259.2	772.5
1992							6.9	14.2	74.0	232.5
1993							20.5	25.0	26.5	209.0
1994							1.3	2.2	3.4	15.3
1995							9.9	12.6	14.1	16.6
1996							9.9	21.5	10.9	12.3
1997							27.2	24.4	20.9	17.4
1998							8.4	11.5	11.7	11.0
1999							17.9	25.6	7.5	7.1
2000							7.1	8.1	13.7	14.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-26 (Continued)

COAL REFUSE KCl-EXTRACTABLE NH_3-N (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	45 to 60 cm[1]									
1987									14.0	26.2
1988									27.0	105.0
1989									9.8	134.0
1990									157.1	9.8
1991									145.4	810.0
1992									146.0	490.5
1993									37.0	265.0
1994									9.4	142.6
1995									15.1	158.8
1996									11.8	59.3
1997									23.6	99.2
1998									12.3	184.2
1999									10.8	6.1
2000									21.1	15.4

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-27

COAL REFUSE KCl-EXTRACTABLE NO_3-N (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	3.9	124.0	121.0	41.6	74.2	78.2	80.0	52.3	304.0	64.4
1988	1.4	58.2	43.0	69.4	94.1	31.8	76.6	167.0	354.0	249.0
1989	0.6	28.6	49.9	15.9	28.9	38.2	52.7	40.6	119.0	123.0
1990	0.7	13.0	19.4	5.3	17.3	20.0	23.8	29.5	58.5	28.4
1991	1.0	9.5	5.0	3.5	8.5	8.5	3.5	11.5	46.5	62.5
1992	5.0	12.5	11.5	7.0	13.5	31.5	15.0	33.0	22.5	42.0
1993	1.0	7.0	5.0	3.0	10.0	13.0	16.0	16.0	11.0	17.0
1994	0.3	1.4	0.2	0.7	1.3	2.6	1.4	0.4	0.4	1.3
1995	1.7	5.3	6.7	19.4	25.8	29.9	18.6	7.0	13.3	48.7
1996	0.4	7.7	1.6	14.2	14.6	11.8	10.1	17.1	30.1	12.9
1997	0.1	1.8	2.3	0.1	38.8	15.7	12.5	18.8	33.6	24.7
1998	0.1	7.9	10.3	43.0	28.7	15.9	27.7	40.7	71.9	86.6
1999	7.5	12.0	13.4	18.8	53.3	35.0	21.3	93.3	71.3	79.4
2000	0.3	11.8	3.7	1.6	28.3	15.1	27.1	36.7	53.9	59.7

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-27 (Continued)

COAL REFUSE KCl-EXTRACTABLE NO_3-N (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	15 to 30 cm									
1987	1.3	92.8	121.0	11.8	31.0	28.0	114.0	10.4	398.0	194.0
1988	0.5	45.2	28.1	30.7	45.5	45.5	60.5	130.0	236.0	164.0
1989	0.9	40.6	60.2	18.5	47.9	24.4	40.5	76.1	58.7	83.8
1990	0.5	11.0	15.7	6.9	16.7	12.2	12.2	101.9	219.4	87.8
1991	0.0	12.5	4.5	6.0	9.5	7.0	3.5	14.5	84.5	162.0
1992	4.0	13.0	27.0	7.5	7.5	14.0	11.0	14.0	52.5	68.5
1993	1.0	9.0	3.0	2.0	4.0	6.0	8.0	9.0	11.0	18.0
1994	0.6	1.2	1.3	0.6	1.1	2.2	1.0	1.3	0.6	2.6
1995	1.0	6.4	6.7	6.7	18.1	18.7	7.3	8.0	19.2	33.7
1996	0.3	4.9	2.7	2.9	11.0	8.2	5.1	16.5	17.0	9.9
1997	0.1	0.1	1.6	0.1	13.8	12.3	6.1	12.6	24.2	34.5
1998	0.1	3.6	6.6	19.5	10.2	8.1	28.7	14.1	32.6	40.7
1999	13.5	14.4	15.7	12.2	29.5	22.6	22.1	68.6	47.1	43.5
2000	0.1	5.9	3.3	3.8	19.6	14.0	29.7	19.2	47.7	53.2

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-27 (Continued)

COAL REFUSE KCl-EXTRACTABLE NO_3-N (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	30 to 45 cm[1]									
1987							26.8	2.3	4.0	8.9
1988							14.7	26.0	60.0	13.0
1989							53.9	68.5	31.2	21.4
1990							18.0	43.9	323.0	66.2
1991							10.5	0.0	131.5	58.5
1992							14.5	20.0	132.0	86.5
1993							7.0	8.0	17.0	13.0
1994							2.0	3.5	3.6	14.1
1995							19.8	15.6	36.3	69.5
1996							7.8	15.2	16.7	44.7
1997							5.9	5.3	31.2	42.4
1998							16.1	16.0	22.1	27.7
1999							18.8	28.6	24.9	33.9
2000							19.0	21.0	30.0	35.4

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-27 (Continued)

COAL REFUSE KCl-EXTRACTABLE NO_3-N (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	45 to 60 cm[1]									
1987									0.9	0.9
1988									7.1	3.4
1989									17.0	5.6
1990									144.7	15.7
1991									67.5	32.0
1992									80.5	61.0
1993									25.0	11.0
1994									4.0	2.0
1995									39.5	34.5
1996									23.9	76.9
1997									16.3	37.0
1998									24.0	36.9
1999									53.1	52.0
2000									37.7	38.0

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-28

COAL REFUSE BRAY P1 AVAILABLE P (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	12.5	40	19	10	17	20	2	23	13	22
1988	20.3	191	56	62	53	56	70	115	97	93
1989	3.0	105	49	51	62	64	75	53	66	68
1990	4.5	162	113	125	149	147	147	139	131	143
1991	10.0	122	81	140	144	174	149	144	147	138
1992	5.5	138	158	112	176	192	183	182	178	178
1993	4.3	120	119	103	140	131	124	118	120	125
1994	6.5	118	99	115	122	127	126	141	134	162
1995	6.0	84	81	145	146	147	153	161	156	157
1996	24.0	163	127	147	188	155	168	190	195	180
1997	9.5	127	139	114	195	188	198	221	199	108
1998	11.5	109	127	92	137	127	171	164	179	127
1999	21.0	65	113	97	125	123	152	157	164	176
2000	15.0	171	119	161	192	200	203	280	272	268

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-28 (Continued)

COAL REFUSE BRAY P1 AVAILABLE P (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	15 to 30 cm[1]									
1987	12.0	11	11	9	10	11	2	23	2	27
1988	17.3	33	21	4	9	4	29	56	65	70
1989	0.0	2	3	0	5	2	33	10	59	54
1990	3.5	99	21	19	67	69	78	154	129	137
1991	7.5	21	14	20	69	10	74	81	121	134
1992	4.0	72	28	4	82	71	128	180	176	151
1993	0.3	15	26	13	31	27	95	109	113	117
1994	8.5	50	13	102	15	58	89	114	126	122
1995	5.0	20	15	17	51	11	72	104	126	105
1996	17.5	23	22	9	81	29	85	128	151	159
1997	7.5	23	24	34	76	73	113	188	179	141
1998	11.5	15	14	35	15	26	92	71	154	90
1999	12.0	41	10	22	42	36	62	149	120	126
2000	11.3	67	27	25	76	65	150	152	216	200

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-28 (Continued)

COAL REFUSE BRAY P1 AVAILABLE P (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	30 to 45 cm[1]									
1987							2.2	2.2	19.0	2.2
1988							7.1	58.7	41.3	28.0
1989							19.7	11.5	51.3	77.0
1990							ND[2]	ND	ND	ND
1991							ND	ND	ND	ND
1992							ND	ND	ND	ND
1993							ND	ND	ND	ND
1994							ND	ND	ND	ND
1995							ND	ND	ND	ND
1996							ND	ND	ND	ND
1997							ND	ND	ND	ND
1998							ND	ND	ND	ND
1999							ND	ND	ND	ND
2000							ND	ND	ND	ND

[1]Plots with missing data were not monitored at these depths.
[2]ND = No data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-29

COAL REFUSE TOTAL P (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	645	8,531	6,972	4,161	9,218	9,427	7,052	15,979	15,114	13,726
1988	771	7,643	7,950	6,781	11,308	8,969	6,480	17,547	19,014	18,786
1989	500	5,313	700	3,970	6,938	7,725	6,488	11,475	14,738	15,650
1990	464	7,342	6,388	3,855	7,158	7,209	7,376	13,011	13,263	10,556
1991	491	3,802	3,622	5,168	9,068	7,660	6,056	12,244	14,762	15,167
1992	448	5,011	9,479	3,265	9,462	9,220	7,341	14,863	16,651	13,150
1993	441	4,710	5,226	3,898	8,109	7,163	5,844	17,581	15,458	12,672
1994	391	10,966	5,884	5,149	6,384	8,118	5,254	12,075	13,529	12,546
1995	424	5,176	5,400	5,833	7,968	8,398	5,392	14,339	15,651	13,600
1996	533	6,166	5,732	4,901	9,793	8,198	4,978	16,263	16,082	13,997
1997	505	5,525	7,225	3,443	9,434	8,385	5,936	15,473	16,583	14,842
1998	609	6,236	8,421	5,538	7,878	8,121	6,188	12,293	17,512	15,982
1999	568	4,305	6,226	3,715	8,492	9,312	5,675	18,756	15,584	16,540
2000	420	4,985	9,255	4,486	5,912	6,779	4,542	12,385	14,999	12,020

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-29 (Continued)

COAL REFUSE TOTAL P (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	15 to 30 cm									
1987	624	1,474	1,339	930	3,220	2,330	4,612	5,853	12,776	11,387
1988	697	2,175	2,248	1,272	3,601	2,594	4,666	4,059	11,847	11,313
1989	400	900	1,148	770	1,875	1,425	3,350	2,225	8,500	10,650
1990	419	2,826	1,264	921	2,053	2,209	4,326	5,357	8,577	5,010
1991	475	890	573	1,110	3,458	1,606	4,558	4,284	10,083	9,480
1992	408	1,128	1,080	583	2,853	2,177	4,665	10,084	13,011	8,072
1993	526	535	790	695	1,262	897	3,774	6,831	9,177	6,172
1994	377	2,583	849	4,706	822	5,190	3,702	5,539	10,915	5,300
1995	375	1,192	853	817	2,745	932	3,457	4,465	8,824	5,389
1996	447	1,100	932	734	2,846	1,881	3,284	7,504	13,816	8,967
1997	431	1,361	1,610	1,124	2,869	2,370	4,185	8,568	12,883	9,475
1998	646	1,061	1,132	1,604	1,085	1,277	5,214	3,476	9,350	6,196
1999	388	3,206	716	965	1,651	3,050	3,776	9,297	11,082	8,856
2000	350	1,049	940	1,072	1,560	1,856	3,995	3,591	11,144	5,711

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-29 (Continued)

COAL REFUSE TOTAL P (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	30 to 45 cm[1]									
1987							2,199	1,197	3,768	6,171
1988							1,322	1,076	3,325	4,886
1989							3,075	3,075	4,738	8,363
1990							884	1,352	5,122	2,533
1991							1,574	1,478	2,283	7,049
1992							2,048	1,026	3,612	7,442
1993							4,573	1,271	6,516	2,912
1994							2,172	750	6,019	6,397
1995							2,816	606	1,911	2,375
1996							2,062	1,089	3,359	3,459
1997							1,538	1,028	5,490	5,307
1998							1,069	817	1,944	1,595
1999							1,191	1,253	2,700	1,725
2000							2,062	1,726	2,884	3,000

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-29 (Continued)

COAL REFUSE TOTAL P (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	45 to 60 cm[1]									
1987									765	1,659
1988									977	3,460
1989									1,150	5,200
1990									1,489	2,328
1991									798	4,276
1992									1,060	4,345
1993									3,383	2,727
1994									1,303	5,724
1995									1,024	1,936
1996									1,227	2,276
1997									1,372	3,493
1998									1,028	2,272
1999									7,575	3,842
2000									1,832	2,111

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-30

COAL REFUSE TKN (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	2,772	6,199	5,418	3,836	7,030	6,890	6,378	10,266	12,805	11,692
1988	3,366	6,334	6,155	5,422	7,738	7,172	4,973	9,407	9,778	9,914
1989	3,175	5,425	5,950	4,176	5,975	7,125	5,600	8,275	8,975	9,750
1990	3,051	6,669	5,899	4,142	6,424	6,375	60	8,665	8,322	7,029
1991	3,261	5,032	4,799	6,015	8,723	6,838	5,555	8,395	8,946	9,406
1992	3,360	5,154	7,801	5,647	8,750	7,668	6,176	9,838	10,906	9,430
1993	3,627	5,301	6,198	4,505	8,241	7,802	4,774	10,343	9,696	7,822
1994	4,171	8,391	6,184	5,913	7,453	8,275	4,418	7,740	8,775	8,046
1995	3,187	5,642	6,108	5,931	7,438	6,782	4,757	9,214	9,286	8,397
1996	2,890	5,879	6,286	5,262	7,305	5,985	4,168	9,423	8,858	8,488
1997	3,748	5,765	7,025	4,202	7,852	6,776	4,950	9,017	9,807	8,649
1998	4,294	6,035	7,022	5,338	6,197	6,130	5,007	7,729	9,396	8,148
1999	4,356	5,908	6,588	5,555	6,511	5,882	3,609	9,052	8,435	8,585
2000	3,070	4,334	7,798	4,088	6,076	5,564	3,871	8,258	8,304	6,914
					15 to 30 cm					
1987	2,306	3,655	3,867	2,939	3,310	2,883	4,782	6,666	12,031	11,553
1988	3,429	3,942	4,368	3,244	3,357	3,527	4,883	4,940	8,276	7,518
1989	3,550	3,200	2,819	3,280	4,200	3,625	3,850	4,750	6,675	7,625
1990	3,512	4,803	3,112	3,424	3,591	3,050	4,314	5,533	6,139	4,687
1991	4,003	3,520	3,341	3,741	4,843	3,364	4,757	6,109	7,966	6,907
1992	3,964	3,133	3,017	3,290	4,020	3,271	4,482	8,072	9,431	7,392
1993	3,768	3,028	4,040	3,364	4,372	2,721	3,496	6,637	7,398	5,285
1994	4,221	4,693	4,077	5,940	3,831	4,985	3,924	5,178	7,291	4,593
1995	3,477	3,621	3,284	2,812	3,844	2,671	3,485	4,996	6,503	5,325
1996	3,089	3,566	3,740	3,020	3,903	3,034	3,484	6,405	8,181	6,141

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-30 (Continued)

COAL REFUSE TKN (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							4,272	4,482	6,953	6,422
1988							3,975	4,049	5,225	4,736
1989							4,200	4,525	5,050	7,800
1990							2,923	3,255	5,298	3,256
1991							3,769	4,798	4,314	6,485
1992							3,253	5,254	5,512	5,826
1993							4,249	4,378	6,472	4,597
1994							3,320	3,771	4,814	5,463
1995							2,783	3,110	3,639	3,495
1996							3,539	3,750	4,131	3,698
----------45 to 60 cm[1]----------										
1987									4,528	3,969
1988									3,400	4,403
1989									3,450	6,400
1990									3,297	3,695
1991									3,682	5,897
1992									4,615	4,998
1993									5,794	4,827
1994									3,498	5,958
1995									3,192	3,347
1996									3,352	3,402

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-31

COAL REFUSE EXCHANGEABLE Ca (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number 1	2	3	4	5	6	7	8	9	10
					0 to 15 cm					
1987	4,246	3,966	4,163	4,291	4,690	5,006	5,207	5,005	4,524	4,430
1988	18,200	64,517	58,683	23,217	57,167	22,517	47,950	39,900	59,967	33,133
1989	22,773	19,425	19,483	9,135	14,817	13,988	7,012	26,717	11,667	11,958
1990	34,500	22,954	21,493	16,254	20,743	21,211	8,687	17,814	8,153	13,743
1991	3,875	9,486	9,825	11,726	10,875	11,936	5,912	10,590	9,470	9,108
1992	32,095	24,302	15,027	13,627	14,688	10,582	7,712	8,027	9,520	15,610
1993	25,470	23,323	22,250	10,537	15,927	18,132	6,442	9,312	9,837	11,073
1994	26,058	15,897	16,527	7,940	15,617	13,447	6,412	15,337	14,858	16,344
1995	33,107	27,320	22,840	8,787	10,960	10,649	5,604	7,194	6,865	9,914
1996	38,943	26,798	20,942	4,525	3,927	3,045	2,131	2,198	2,403	3,462
					15 to 30 cm					
1987	4,105	4,331	4,388	4,410	4,629	4,691	4,980	4,510	4,630	4,818
1988	55,650	32,550	70,233	44,917	62,067	40,950	53,317	57,050	70,933	23,940
1989	25,352	21,502	21,852	19,740	22,563	24,430	16,135	21,572	16,182	20,708
1990	32,100	21,949	22,363	20,274	18,281	19,420	15,193	17,313	20,322	27,084
1991	15,938	18,691	18,843	35,993	35,083	40,298	22,537	31,368	25,477	23,260
1992	31,908	25,853	33,355	30,882	28,268	32,398	13,930	17,792	16,567	27,043
1993	29,308	22,845	32,657	28,538	28,608	32,435	12,963	22,110	20,640	21,107
1994	27,272	21,392	25,475	10,670	25,452	21,952	11,370	15,792	3,122	25,549
1995	33,830	32,092	31,287	30,330	26,107	37,085	11,248	28,997	21,717	24,155
1996	37,940	44,228	36,878	32,492	31,663	35,770	5,018	22,552	3,945	20,067

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-31 (Continued)

COAL REFUSE EXCHANGEABLE Ca (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							5,123	4,862	3,962	4,574
1988							25,200	56,467	67,083	23,485
1989							19,553	23,042	20,580	7,325
1990							19,328	19,651	17,028	27,780
1991							36,898	36,607	41,530	28,761
1992							30,252	30,182	22,855	21,490
1993							27,663	31,140	23,032	28,982
1994							16,667	24,425	9,391	18,701
1995							32,170	34,912	28,378	27,562
1996							38,033	35,210	32,142	38,407
----------45 to 60 cm[1]----------										
1987									3,935	4,343
1988									29,388	25,165
1989									18,282	5,746
1990									2,601	19,860
1991									36,513	32,704
1992									35,583	18,410
1993									27,920	30,288
1994									12,284	16,076
1995									34,748	29,092
1996									32,842	29,272

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-32

COAL REFUSE EXCHANGEABLE Mg (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
0 to 15 cm										
1987	282	1,575	892	734	1,042	981	939	1,609	1,529	1,575
1988	861	335	814	1,598	639	1,706	762	544	672	180
1989	118	594	494	520	795	562	502	900	1,136	1,463
1990	174	425	344	347	571	474	428	858	742	666
1991	152	601	302	400	648	389	392	694	942	937
1992	133	448	454	477	618	530	489	796	816	914
1993	253	463	482	494	724	441	503	778	768	676
1994	199	555	341	419	496	433	452	463	480	700
1995	393	340	360	533	573	572	579	781	862	844
1996	138	292	199	183	304	216	199	385	375	324
15 to 30 cm										
1987	271	711	412	489	733	706	817	801	1,253	1,259
1988	912	1,584	263	1,576	260	1,430	581	449	313	1,028
1989	106	344	505	596	736	497	662	606	1,430	1,744
1990	172	424	351	337	595	508	509	1,049	1,109	743
1991	145	387	193	392	588	260	439	666	1,036	1,141
1992	144	373	343	281	637	382	407	726	1,350	797
1993	347	459	314	267	424	270	399	440	785	484
1994	197	331	178	246	287	352	363	565	608	767
1995	322	203	328	327	444	346	357	439	638	564
1996	154	139	122	113	229	164	138	247	222	329

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-32 (Continued)

COAL REFUSE EXCHANGEABLE Mg (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm[1]----------										
1987							599	349	617	1,004
1988							830	1,071	470	614
1989							540	551	1,087	461
1990							448	435	1,118	641
1991							386	525	805	1,076
1992							358	443	902	1,043
1993							316	341	910	368
1994							317	338	627	628
1995							251	302	404	665
1996							151	175	181	322
----------45 to 60 cm[1]----------										
1987									273	550
1988									174	557
1989									700	202
1990									580	592
1991									467	627
1992									768	827
1993									582	368
1994									621	520
1995									353	528
1996									173	264

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-33

COAL REFUSE EXCHANGEABLE Na (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
	0 to 15 cm									
1987	13.0	116.0	106.0	52.7	95.5	128.0	95.7	189.0	246.0	224.0
1988	110.0	19.0	91.0	200.0	102.0	189.0	111.0	68.0	78.0	9.0
1989	53.0	68.0	63.0	48.0	40.0	33.0	22.0	51.0	92.0	124.0
1990	8.1	21.0	18.6	14.0	16.3	29.0	23.3	74.4	69.8	59.1
1991	18.0	19.0	16.0	19.0	15.0	7.0	11.0	37.0	53.0	75.0
1992	37.0	14.0	30.0	23.0	30.0	31.0	30.0	34.0	60.0	56.0
1993	37.0	39.0	36.0	16.0	35.0	9.0	14.0	28.0	48.0	29.0
1994	12.0	18.0	14.0	12.0	12.0	12.0	12.0	12.0	13.0	55.0
1995	87.0	105.0	93.0	101.0	89.0	86.0	116.0	120.0	139.0	136.0
1996	16.0	22.0	18.0	14.0	14.0	16.0	6.0	13.0	17.0	22.0
	15 to 30 cm									
1987	15.4	33.9	36.6	10.0	32.6	43.7	92.9	118.0	281.0	241.0
1988	54.0	154.0	35.0	223.0	28.0	195.0	70.0	39.0	19.0	33.0
1989	43.0	50.0	43.0	43.0	14.0	5.0	32.0	13.0	104.0	151.0
1990	7.0	22.1	10.5	12.8	12.8	24.4	29.1	77.9	95.4	69.8
1991	16.0	18.0	13.0	13.0	14.0	7.0	14.0	30.0	95.0	91.0
1992	20.0	21.0	25.0	12.0	28.0	12.0	17.0	68.0	120.0	66.0
1993	27.0	34.0	37.0	25.0	25.0	11.0	18.0	25.0	62.0	40.0
1994	12.0	12.0	12.0	12.0	12.0	12.0	13.0	26.0	25.0	45.0
1995	88.0	82.0	96.0	83.0	79.0	79.0	109.0	99.0	142.0	136.0
1996	12.0	17.0	18.0	15.0	21.0	14.0	9.0	19.0	22.0	41.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-33 (Continued)

COAL REFUSE EXCHANGEABLE Na (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
						30 to 45 cm[1]				
1987										
1988							23.7	32.2	88.2	117.0
1989							151.0	208.0	36.0	33.0
1990							22.0	11.0	64.0	79.0
1991							17.5	33.7	96.7	51.1
1992							8.0	14.0	53.0	83.0
1993							12.0	16.0	54.0	114.0
1994							27.0	21.0	65.0	36.0
1995							6.0	15.0	32.0	33.0
1996							107.0	88.0	102.0	141.0
							14.0	12.0	16.0	31.0
						45 to 60 cm[1]				
1987										
1988									40.7	63.7
1989									9.0	29.0
1990									11.6	41.0
1991									45.5	53.6
1992									22.0	68.0
1993									53.0	96.0
1994									33.0	38.0
1995									45.0	34.0
1996									96.0	111.0
									13.0	24.0

[1]Plots with missing data were not monitored at these depths.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-34

COAL REFUSE EXCHANGEABLE K (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
0 to 15 cm										
1987	31	293	279	199	412	423	314	629	710	652
1988	379	8	180	986	232	778	247	149	58	34
1989	29	160	195	145	183	254	274	336	473	524
1990	16	249	185	172	216	254	327	410	488	379
1991	18	128	130	188	296	324	294	470	611	551
1992	39	161	295	222	308	396	383	604	596	529
1993	31	143	161	141	223	165	200	474	328	425
1994	31	215	179	211	176	233	242	195	154	263
1995	16	142	189	181	220	231	232	396	549	481
1996	28	92	121	113	146	175	129	307	333	287
15 to 30 cm										
1987	38	47	68	74	124	118	202	254	691	543
1988	173	670	14	673	35	496	170	81	ND[1]	225
1989	37	56	63	62	40	72	121	90	280	389
1990	14	82	62	64	69	86	133	199	280	200
1991	16	55	55	60	67	68	98	113	355	319
1992	36	72	243	58	113	85	172	306	474	333
1993	21	135	78	66	64	50	93	140	231	210
1994	19	93	95	116	73	123	122	220	565	150
1995	25	56	90	78	77	64	105	125	242	181
1996	18	47	45	62	45	56	67	119	202	189

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AI-34 (Continued)

COAL REFUSE EXCHANGEABLE K (mg/kg) IN TEN PLOTS ON ST. DAVID COAL REFUSE PILE

Year	Plot Number									
	1	2	3	4	5	6	7	8	9	10
----------30 to 45 cm^2----------										
1987							79	62	187	290
1988							488	1,017	1,127	216
1989							119	105	156	143
1990							57	55	216	127
1991							60	67	112	252
1992							111	74	212	286
1993							68	51	226	244
1994							101	104	343	197
1995							59	42	81	153
1996							52	56	93	113
----------45 to 60 cm^2----------										
1987									54	74
1988									30	67
1989									34	60
1990									54	124
1991									51	205
1992									100	208
1993									114	108
1994									316	231
1995									56	125
1996									60	106

[1]ND = No data.
[2]Plots with missing data were not monitored at these depths.

APPENDIX AII

CONCENTRATIONS OF METALS IN FORAGE TISSUE

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1

CONCENTRATION OF METALS IN FORAGE GROWN ON TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Year	Plot Number 2	3	4	5	6	7	8	9	10
					Al (mg/kg)				
1988	1,591.7	1,219.3	1,912.0	1,079.7	350.0	176.3	302.0	503.0	448.7
1989	180.7	156.5	156.5	157.5	156.0	157.5	156.7	156.7	156.5
1990	504.7	239.4	119.5	119.2	139.5	611.3	172.7	159.3	ND
1991	2.0	1.5	1.0	1.5	1.5	1.0	1.5	1.5	1.0
1992	145.7	103.3	37.7	40.3	44.0	38.0	46.3	58.0	35.0
1993	55.3	37.7	33.3	41.0	37.0	39.5	40.0	42.3	47.7
1994	23.0	18.3	18.0	18.0	19.5	25.0	13.7	7.7	6.0
					Ca (mg/kg)				
1988	4,231	5,311	5,138	4,959	4,910	3,716	3,866	4,576	4,935
1989	3,314	3,395	2,873	3,331	3,838	3,597	4,861	6,627	6,636
1990	5,658	6,458	6,985	5,788	6,855	6,060	6,295	6,743	ND
1991	17,433	12,533	10,150	15,283	11,300	10,833	16,058	16,417	15,008
1992	10,089	10,042	11,357	13,572	12,328	8,549	10,804	9,272	9,612
1993	3,650	3,760	3,466	3,970	3,671	4,153	3,411	3,625	3,725
1994	4,926	6,181	6,265	5,475	7,313	7,904	5,186	3,678	3,384
1995	5,274	6,888	6,621	5,840	5,190	4,904	4,105	3,540	3,751
1996	4,172	6,697	5,381	5,302	4,494	5,836	4,158	3,877	3,601

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1 (Continued)

CONCENTRATION OF METALS IN FORAGE GROWN ON TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Year	Plot Number 2	3	4	5	6	7	8	9	10
					Cd (mg/kg)				
1988	5.91	5.23	4.35	7.58	6.38	4.04	5.24	6.35	5.66
1989	3.93	2.77	1.75	2.81	3.12	1.60	3.66	4.23	3.96
1990	7.89	6.94	3.48	4.41	6.90	5.29	5.68	4.80	ND
1991	6.63	4.21	2.01	5.70	3.01	2.46	5.47	4.69	4.91
1992	4.38	3.88	1.89	4.19	3.53	2.51	4.24	5.36	4.68
1993	4.17	2.76	1.68	3.12	3.38	2.34	4.07	3.02	4.17
1994	4.05	1.33	1.40	3.53	2.79	2.16	3.61	5.42	4.03
1995	4.12	2.62	1.78	3.32	2.62	2.83	3.63	4.12	3.24
1996	4.61	2.09	1.93	4.24	2.93	2.08	4.56	5.60	3.98
					Cr (mg/kg)				
1988	18.10	20.40	13.80	21.73	13.47	5.96	9.91	12.67	10.97
1989	0.90	0.36	0.17	0.25	0.24	0.26	0.28	0.25	1.03
1990	2.84	0.55	0.92	1.19	1.06	10.99	1.16	1.51	ND
1991	0.28	0.38	0.25	0.25	<0.15	0.12	0.53	0.22	0.10
1992	1.13	1.75	0.27	0.20	0.30	0.30	0.30	0.27	0.53
1993	0.80	0.65	0.45	0.90	0.40	0.75	0.43	0.37	0.55
1994	0.35	0.35	0.30	0.30	0.33	0.25	0.25	0.25	0.25
1995	0.25	0.25	0.23	0.33	0.20	<0.15	0.20	<0.15	<0.15
1996	<0.15	0.25	0.10	0.10	0.10	0.27	0.50	<0.15	<0.15

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1 (Continued)

CONCENTRATION OF METALS IN FORAGE GROWN ON TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Year	Plot Number 2	3	4	5	6	7	8	9	10
					Cu (mg/kg)				
1988	28.07	21.63	18.83	29.20	17.33	9.91	16.58	26.13	26.10
1989	7.32	5.23	4.47	5.99	5.64	4.83	8.38	7.78	8.71
1990	15.77	9.14	10.31	12.18	12.23	16.43	14.17	12.67	ND
1991	8.95	7.07	9.70	9.43	11.57	8.60	10.33	9.93	9.47
1992	5.57	7.03	6.40	7.40	7.33	6.37	6.33	6.30	6.53
1993	6.83	8.10	7.07	11.17	8.80	9.70	8.97	8.73	8.07
1994	4.63	3.75	3.73	4.20	6.13	5.00	6.13	6.27	6.90
1995	4.23	4.07	6.03	7.17	6.87	6.10	4.50	4.33	5.80
1996	4.40	6.23	6.80	6.20	5.03	6.80	5.30	6.30	5.33
					Fe (mg/kg)				
1988	2,588	1,979	1,768	2,150	1,199	355	267	395	377
1989	162	87	91	87	103	94	84	86	91
1990	1,256	126	142	183	146	433	174	136	ND
1991	93	96	92	71	63	91	97	91	103
1992	215	180	82	88	87	59	75	73	75
1993	48	27	22	36	24	26	30	31	32
1994	53	36	35	35	41	43	37	35	36
1995	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND
1996	ND	ND	ND	ND	ND	ND	ND	ND	ND

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1 (Continued)

CONCENTRATION OF METALS IN FORAGE GROWN ON TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Year	Plot Number 2	3	4	5	6	7	8	9	10
					K (mg/kg)				
1988	2,531	3,326	2,824	2,802	2,650	3,101	2,222	2,303	2,215
1989	5,374	5,811	6,361	5,848	6,426	6,439	4,971	3,592	3,502
1990	19,904	12,393	17,268	23,093	25,507	22,117	28,102	30,640	ND
1991	19,535	18,193	20,027	18,102	24,810	22,968	20,468	20,702	20,735
1992	16,767	21,133	20,667	23,000	21,950	21,017	21,200	20,300	21,817
1993	23,481	24,914	24,414	26,864	25,747	28,364	26,714	22,299	22,431
1994	20,192	15,950	18,546	16,900	20,242	18,217	34,166	37,067	33,500
1995	22,128	15,242	18,678	26,712	27,551	35,603	28,114	34,355	33,932
1996	25,117	18,637	27,945	23,667	25,561	26,907	28,198	34,420	30,796
					Mg (mg/kg)				
1988	1,900	1,829	1,512	1,777	1,780	1,706	1,456	1,660	1,680
1989	2,587	1,593	1,462	2,021	1,842	1,784	2,901	2,689	2,806
1990	3,055	1,595	1,487	2,283	2,019	2,074	2,948	3,319	ND
1991	3,808	1,875	1,983	3,983	2,142	2,025	5,000	3,642	3,275
1992	2,365	1,940	2,142	2,642	2,499	2,040	2,555	3,735	2,945
1993	1,600	1,384	1,394	2,090	1,457	1,814	2,212	2,447	2,535
1994	2,266	1,758	1,855	2,210	1,957	1,754	2,564	2,515	3,086
1995	2,044	1,880	2,380	2,910	2,652	3,143	2,713	2,698	3,261
1996	2,305	1,601	2,997	2,804	2,807	2,171	2,564	3,312	2,759

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1 (Continued)

CONCENTRATION OF METALS IN FORAGE GROWN ON TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Year	Plot Number 2	3	4	5	6	7	8	9	10
					Mn (mg/kg)				
1988	99	106	98	132	101	69	67	64	66
1989	80	70	34	83	63	64	89	86	131
1990	186	73	41	67	69	127	119	101	ND
1991	121	53	27	93	40	49	141	109	133
1992	89	49	33	44	33	45	48	97	65
1993	91	49	41	76	52	42	47	31	61
1994	134	44	17	53	19	28	41	55	60
1995	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996	ND	ND	ND	ND	ND	ND	ND	ND	ND
					Na (mg/kg)				
1988	43.0	29.7	34.6	14.5	11.0	17.3	6.5	24.0	14.1
1989	22.2	14.1	12.5	10.3	11.2	12.3	50.6	13.6	17.7
1990	39.3	20.8	6.0	12.5	7.7	13.8	14.9	32.2	ND
1991	149.0	37.3	127.0	62.3	51.7	139.3	358.3	291.0	303.3
1992	30.3	24.0	19.7	28.0	22.3	14.7	42.7	49.7	45.7
1993	16.3	8.3	6.3	6.0	11.3	10.0	20.0	15.7	12.7
1994	10.0	7.3	8.0	5.0	7.3	6.6	8.5	7.0	11.3
1995	ND	ND	ND	ND	ND	ND	ND	ND	ND
1996	ND	ND	ND	ND	ND	ND	ND	ND	ND

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1 (Continued)

CONCENTRATION OF METALS IN FORAGE GROWN ON TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Year	Plot Number 2	3	4	5	6	7	8	9	10
					Mn (mg/kg)				
1988	17.87	12.97	13.43	17.75	10.17	6.08	10.82	13.93	12.26
1989	7.96	2.89	1.57	4.86	3.30	1.97	8.05	7.07	8.01
1990	13.66	4.42	3.84	4.14	4.70	8.18	6.11	4.24	ND
1991	12.00	3.63	1.57	7.30	2.50	1.83	12.57	12.67	7.30
1992	6.10	1.67	1.07	4.17	2.73	1.40	5.07	6.23	4.33
1993	6.33	1.40	1.57	4.77	2.20	3.37	5.37	4.67	7.10
1994	3.57	0.63	0.80	1.80	1.33	1.03	2.70	3.50	4.07
1995	3.87	1.40	0.93	2.40	1.60	2.23	3.73	3.80	4.90
1996	4.00	1.10	1.53	2.10	1.75	1.47	4.07	5.50	4.73
					Pb (mg/kg)				
1988	7.92	7.19	7.10	9.10	6.47	2.72	4.41	7.50	6.30
1989	1.51	0.54	0.44	0.52	0.64	0.76	0.70	0.70	0.87
1990	7.52	0.48	0.60	0.83	0.75	4.02	0.76	0.63	ND
1991	0.32	0.50	0.47	0.50	0.58	0.35	0.38	0.35	0.39
1992	1.25	0.94	0.61	0.43	0.43	0.54	0.54	0.52	0.04
1993	0.15	0.08	0.04	0.10	0.05	0.08	0.08	0.10	0.36
1994	0.27	0.19	0.18	0.22	0.19	0.18	0.13	0.13	0.08
1995	0.70	0.71	0.63	0.55	0.36	0.23	0.20	0.15	0.13
1996	0.16	0.54	0.45	0.40	0.20	1.07	0.47	0.25	0.30

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AII-1 (Continued)

CONCENTRATION OF METALS IN FORAGE GROWN ON TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Year	Plot Number								
	2	3	4	5	6	7	8	9	10
	Zn (mg/kg)								
1988	240	231	167	257	188	137	166	178	176
1989	186	137	108	226	189	136	211	216	235
1990	207	122	82	96	131	100	132	133	ND
1991	165	111	60	233	97	83	149	111	103
1992	138	99	63	134	100	85	107	135	107
1993	122	87	81	123	111	94	109	102	161
1994	115	64	55	119	75	81	93	94	93
1995	128	82	73	98	83	81	97	91	97
1996	161	80	80	121	107	84	118	143	135

[1]ND = no data.

APPENDIX AIII

CONCENTRATIONS OF CONSTITUENTS IN SURFACE RUNOFF WATER

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-1

CONCENTRATION OF CONSTITUENTS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	pH	EC	Acidity	Alka-linity	BOD_5	TSS	TDS	Total P	Cl	SO_4	NH_3-N	NO_3-N	NO_2-N
			dS/m					mg/L						
1	12/9/87	2.6	0.21	1,320	<1	3	889	2,527	3.54	8	1,310	63.72	0.83	0.273
1	1/27/88	2.8	0.18	707	<1	2	36,120	1,847	1.57	5	1,290	30.9	0.39	0.072
1	4/7/88	2.7	0.19	692	<1	12	69,770	4,946	49.7	17	1,140	2.75	0.32	0.004
1	11/16/88	2.5	0.31	2,070	<1	5	713	4,955	ND[1]	30	9,782	0.5	ND	ND
1	1/26/89	2.5	0.35	2,668	<1	5	39,510	18,966	41.5	34	4,294	1	ND	ND
1	4/5/89	2.8	0.23	467	<1	3	1,935	2,523	2.82	13.5	1,201	0.3	28.5	0.02
1	1/21/90	2.9	0.18	497	<1	3	779	1,359	2.43	1.4	1,200	0.37	0.43	0.008
1	5/7/90	2.9	0.17	156	<1	1	215	1,229	0.81	0.9	870	0.98	0.65	0.005
1	11/28/90	2.8	0.24	733	<1	1	6,853	17,472	5.53	0.5	2,132	0.35	<0.01	0.006
1	3/28/91	2.4	0.51	4,068	<1	12	7,123	7,819	24.1	0.2	5,032	2.22	1.21	0.004
1	8/14/91	2.4	0.52	3,178	<1	3	813	6,557	8.33	3	3,890	0.34	0.42	0.008
1	3/27/92	2.5	0.35	1,929	<1	ND	634	4,350	4.71	3.4	2,910	1.12	1.93	0.003
1	6/17/92	2.5	0.41	1,737	<1	<1	21,640	4,850	ND	1	2,778	1.12	0.71	0.008
1	7/7/92	2.6	0.35	1,182	<1	ND	2,577	3,567	5.41	3.7	1,076	4.25	0.78	0.006
1	11/12/92	2.9	0.2	291	<1	<1	4,198	2,267	4.98	1	1,180	4.06	0.9	0.003
1	4/29/93	2.4	0.97	8,532	<1	104	35,247	21,541	126	3	10,840	34.8	1.54	0.172
1	4/12/94	2.6	0.3	624	<1	<1	158,740	80,764	13.32	10.6	2,930	70.5	1.56	0.006
1	12/7/94	2.5	0.36	4,198	<1	ND	614	6,798	0.15	4.3	4,055	0.84	1.7	0.004
1	4/11/95	2.8	0.28	751	<1	<1	26,110	6,492	10.89	5.2	1,608	15.42	1.28	0.007
2	12/9/87	5.5	0.23	622	14	6	181	3,107	1.73	42	1,040	10.4	113	0.487
2	1/27/88	5.3	0.22	8.0	6	4	1,683	3,460	7.44	11	1,498	8.43	25.25	0.142
2	4/7/88	5.9	0.11	23	4	3	105	1,123	0.6	<1	505	6.06	4.42	0.017
2	11/16/88	4.7	0.14	102	7	11	6,585	6,509	ND	<1	2,684	5.4	<0.01	<0.001
2	7/24/89	4.8	0.17	40	334	50	370	1,833	1.42	16	720	4.12	4.8	0.48
2	1/21/90	5.8	<0.01	30	4.38	10	130	42	0.9	4.3	18	1.47	0.42	0.14
2	5/7/90	5.2	0.01	5.0	7	3	21	841	0.33	0.9	591	1.03	0.96	0.014
2	11/28/90	4.5	0.12	17	<1	2	112	1,222	0.53	1	830	1.09	0.4	0.009
2	3/28/91	6.2	0.01	17	13	5	30	86	2.75	2.7	24	0.67	0.83	0.028
2	5/8/91	5.0	0.09	5.0	11	4	20	862	0.37	0.9	520	0.37	0.7	0.011
2	10/30/91	3.7	0.16	14	<1	4	15	1,551	0.13	5.5	1,012	3.67	4.42	0.008
2	3/9/92	3.9	0.14	9.0	<1	2	24	1,320	0.16	1.9	926	2.93	4.6	0.015
2	6/18/92	6.2	0.01	22	15	<1	601	435	0	2.5	525	0.02	1.44	0.097

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-1 (Continued)

CONCENTRATION OF CONSTITUENTS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	pH	EC	Acidity	Alka-linity	BOD_5	TSS	TDS	Total P	Cl	SO_4	NH_3-N	NO_3-N	NO_2-N
			dS/m	mg/L										
2	7/8/92	5.7	0.12	20	13	ND	44	982	0.51	6.1	570	1.74	1.76	0.006
2	11/12/92	3.7	0.07	11	<1	<1	161	505	0.41	2.4	320	0.88	1.04	0.006
2	4/9/93	4.6	0.14	16	9	<1	17	1,259	0.22	2.6	848	0.06	0.58	0.008
2	6/18/93	3.9	0.14	25	<1	3	39	1,123	0.31	4.7	736	1.3	1.13	0.012
2	7/14/93	4.1	0.11	24	<1	<1	186	893	0.65	3	571	0.45	0.63	0.006
2	11/17/93	4.0	0.11	9.0	<1	<1	24	1,088	ND	9.1	27	0.01	0.16	0.001
2	5/9/96	3.9	0.11	24	<1	ND	49	813	0.3	4.7	498	0.24	1.00	0.001
3	12/9/87	6.0	0.17	10	14	9	108	2,086	0.75	14	660	0.7	17.2	0.055
3	1/27/88	6.1	0.21	17	42	5	776	2,377	3.96	17	1,428	1.76	20.14	0.725
3	4/7/88	7.2	0.15	52	40	5	49	1,613	0.63	8	971	1.55	22.48	0.408
3	11/16/88	7.2	0.03	22	56	ND	795	517	ND	1	613	10	<0.01	<0.001
3	1/26/89	5.6	0.05	6.0	15	22	112	472	1.29	2	340	2.8	<0.01	<0.001
3	2/5/90	6.7	0.02	470	14.2	ND	119	211	1.02	17.3	20	1.76	1.62	0.25
3	11/28/90	6.8	0.11	265	18	4	28	1,127	0.97	1.5	643	0.12	<0.01	0.008
3	7/31/92	6.7	0.07	2.7	42	21	34	588	2.48	2.4	2	2.8	0.74	1.58
3	4/9/93	6.9	0.07	8.0	29	4	84	596	0.92	2.1	373	0.3	0.47	0.005
3	7/14/93	6.9	0.05	41	40	4	10	462	1.18	9.6	226	0.32	0.95	0.012
3	4/12/94	6.8	0.09	14	29	8	54	808	0.87	3.6	459	9.48	3.69	0.212
3	4/11/95	7.2	0.05	16	24	<1	127	283	1.21	5.1	176	7.37	1.42	0.158
4	12/9/87	7.2	0.14	158	385	ND	768	874	42.3	76	20	79.3	0.62	0.007
4	12/21/87	6.6	0.14	52	19	4	23	1,417	0.58	16	845	0.2	<0.01	<0.001
4	1/27/88	6.3	0.09	11	49	52	231	834	2.37	32	398	21	0.72	0.362
4	11/16/88	7.2	0.01	25	38	ND	44	100	ND	<1	564	4.2	<0.01	<0.001
4	1/21/90	6.2	<0.01	31	5.02	6	12	44	0.19	3.2	2	0.26	0.22	0.036
4	11/28/90	7.0	0.1	41	25	5	102	946	ND	1.8	614	0.26	9.8	0.023
4	5/8/91	7.4	0.07	33	31	3	16	632	1.01	1.6	245	0.12	13.7	0.02
4	8/14/91	6.9	0.01	21	18	<1	19	85	1.15	1.9	6	0.04	1.2	0.005
4	4/22/92	7.1	0.03	52	27	2	38	326	1.58	5.4	63	0.81	8.93	0.084
4	7/27/92	6.9	0.01	54	32	3	57	37	1.16	5.2	5	2.4	0.66	0.033
4	11/12/92	7.1	0.08	25	56	<1	108	742	3.09	3.1	373	0.25	1.88	0.012
4	4/20/93	6.8	0.02	15	47	4	19	169	1.32	2.5	58	0.74	0.84	0.024
4	4/12/94	7.0	0.03	5.0	41	10	64	228	2.81	3	538	1.32	9.08	0.062

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-1 (Continued)

CONCENTRATION OF CONSTITUENTS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	pH	EC	Acidity	Alka-linity	BOD_5	TSS	TDS	Total P	Cl	SO_4	NH_3-N	NO_3-N	NO_2-N
			dS/m	----------				mg/L						
5	12/9/87	6.6	0.03	21	28	ND	128	198	4.55	3	65	4.85	0.52	0.005
5	12/21/87	6.8	0.19	54	27	3	50	2,758	0.6	44	1,573	0.3	<0.01	<0.001
5	1/27/88	6.7	0.15	8.7	66	15	314	1,989	4.52	51	1,331	1.78	4.2	0.15
5	4/7/88	7.2	0.12	6.0	92	6	14	1,188	0.74	5	642	1.71	0.64	0.015
5	11/16/88	7.4	0.02	20	40	ND	75	210	ND	1	693	8.8	<0.01	<0.001
5	1/21/90	6.4	<0.01	7.0	5.12	5	45	3	0.17	3.6	2	0.84	0.3	0.045
5	11/28/90	7.0	0.07	7.0	23	5	45	555	1.63	1.6	330	0.16	2.13	0.01
5	5/8/91	6.9	0.04	9.0	48	8	44	328	2.19	7.6	65	0.46	3.82	0.134
5	8/14/91	7.4	0.02	15	73	5	39	168	5.54	6.5	4	0.38	0.84	0.051
5	3/19/92	6.8	0.03	515	22	8	32	248	1.89	4.2	112	0.93	0.09	0.037
5	4/22/92	6.7	0.03	28	25	6	16	308	1.96	6	74	1.24	8.7	0.23
5	7/27/92	7.2	0.05	15	153	11	150	300	9.5	18.3	47	20.7	1.32	0.008
5	11/19/92	6.8	0.04	6.0	26	3	8	377	1.11	3.1	1,412	0.25	2.9	0.37
5	4/20/93	6.6	0.07	2.3	37	4	20	573	1.07	2.1	271	0.27	1.58	0.03
5	7/14/93	7.0	0.03	5.0	54	15	30	225	3.44	4.7	88	2.45	1.25	0.63
5	11/17/93	7.2	0.04	9.0	31	<1	26	350	ND	4.3	163	<0.01	0.58	0.002
6	12/9/87	6.8	0.18	17	31	4	46	2,310	2.34	37	11,700	1.25	1.63	0.009
6	1/27/88	6.7	0.19	5.0	81.7	23	203	2,410	1.45	81	1,416	1.93	2.8	0.102
6	4/7/88	7.3	0.15	9.0	82	9	22	1,496	1.2	12	860	1.7	1.9	0.094
6	11/16/88	7.3	0.03	8.0	30	ND	350	200	ND	1	476	3	<0.01	<0.001
6	1/21/90	6.5	<0.01	6.0	5.96	6	38	26	0.53	4.1	2	0.72	0.32	0.048
6	5/7/90	6.9	0.01	8.0	19	5	4	52	1.4	2.6	21	5.56	0.84	0.031
6	11/28/90	7.0	0.04	43	23	9	33	282	1.6	1.8	169	0.11	1.83	0.028
6	7/27/92	7.0	0.06	64	100	10	69	399	10.36	15.4	163	19.3	0.7	0.014
6	4/9/93	7.3	0.09	15	45	10	43	792	1.33	3.6	513	0.08	0.82	0.024
6	4/12/94	5.8	0.1	5.0	13	16	42	996	0.22	4.3	615	1.18	1.96	0.017
7	12/9/87	6.9	0.04	17	32	ND	200	156	34.8	24	2,850	5.6	0.44	0.042
7	12/21/87	6.9	0.17	2.2	31	3	ND	2,148	0.38	32	1,223	0.1	<0.01	<0.001
7	1/27/88	6.8	0.12	5.0	76.7	20	596	1,415	4.03	24	860	1.26	2.52	0.226
7	4/7/88	7.4	0.06	13	53	6	68	514	0.96	4	224	0.95	1.64	0.06
7	11/16/88	7.3	0.01	22	37	ND	275	205	ND	<1	575	4.2	<0.01	<0.001
7	7/24/89	6.9	0.12	9.0	2	ND	16	124	3.38	14	5	2.74	1	0.044

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-1 (Continued)

CONCENTRATION OF CONSTITUENTS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	pH	EC	Acidity	Alka-linity	BOD_5	TSS	TDS	Total P	Cl	SO_4	NH_3-N	NO_3-N	NO_2-N
			dS/m	mg/L										
7	1/21/90	6.3	<0.01	9.0	4.77	8	25	21	0.15	3.6	2	2.58	0.31	0.046
7	5/7/90	6.9	0.01	32	11	4	2	34	0.81	2.2	19	2.04	0.76	0.075
7	11/28/90	6.9	0.01	7.0	27	18	59	92	3.41	5.1	36	0.84	6.03	0.07
7	7/27/92	6.9	0.01	7.0	24	2	6	43	0.39	10.9	1	2.32	0.61	0.065
7	4/9/93	7.4	0.01	9.0	23	4	18	70	1.58	2.2	20	0.13	2.71	0.025
8	12/9/87	6.8	0.06	7.0	48	ND	302	424	2.65	65	3,180	11	0.34	0.071
8	12/21/87	6.7	0.23	28	16	5	42	3,538	0.76	67	1,704	42.5	<0.01	<0.001
8	1/27/88	6.5	0.16	17	47.8	40	544	1,378	3.14	32	857	5.58	30.31	1.042
8	4/7/88	7.0	0.11	5.0	53	10	24	1,130	1.24	16	622	4.2	15.25	0.532
8	11/16/88	7.3	0.02	7.0	46	ND	225	183	ND	<1	629	9.7	<0.01	<0.001
8	7/24/89	6.5	0.09	2.2	26	7	2	32	1.19	9	2	0.07	0.95	0.058
8	1/21/90	6.4	0.01	5.0	7.8	12	187	255	0.76	4.1	29	1.68	0.74	0.107
8	5/7/90	6.7	0.01	4.0	16.4	11	10	54	1.27	4	16	2.88	1.2	0.054
8	11/28/90	7.0	0.03	35	29	9	22	270	2.09	3.8	130	0.1	1.05	0.016
8	5/8/91	6.8	0.02	6.0	23	3	100	150	2.41	2.6	73	2.44	0.6	0.084
8	4/22/92	6.7	0.01	9.0	13	5	110	64	1.34	4.2	16	0.97	0.95	0.048
8	7/31/92	6.8	0.06	51	127	26	159	419	8.69	12.1	109	25.3	0.73	3.41
8	4/20/93	6.2	0.01	33	13	9	29	3,661	0.95	1.9	2	0.95	0.72	1.18
8	11/17/93	7.6	0.03	13	38	<1	42	284	ND	4.6	124	0.01	0.69	0.004
8	4/12/94	6.4	0.09	4.0	18	21	24	832	3.07	4.1	274	1.92	45.25	0.08
8	12/7/94	7.1	0.05	21	30	ND	74	490	6.94	8.3	215	8.95	19.25	0.046
8	4/11/95	6.9	0.04	27	20	<1	38	336	2.13	3.4	133	1.24	10.9	0.019
9	12/9/87	6.5	0.31	2.1	31	11	262	4,246	2.32	600	2,930	27.4	252.5	0.353
9	1/27/88	6.6	0.18	3.0	39.7	20	1,076	1,977	23.3	84	888	13	117	0.864
9	4/7/88	7.3	0.07	6.0	50	7	74	590	1.61	22	210	5.05	19	0.803
9	11/16/88	6.8	0.08	6.0	31	8	92	918	ND	6	665	8.6	<0.01	<0.001
9	1/26/89	6.0	0.05	5.0	28	14	67	465	2.45	3	204	3.8	<0.01	<0.001
9	7/24/89	7.0	0.13	76	13	ND	2	51	1.67	15	4	2.42	1.5	0.163
9	1/21/90	6.6	<0.01	32	6.41	8	44	22	0.97	4	2	1.67	0.35	0.068
9	5/7/90	7.0	0.01	17	24.3	3	5	45	0.9	4.6	16	4.6	1	0.047
9	11/28/90	7.0	0.02	5.0	33	15	115	64	3.76	8	65	0.27	2.75	0.072
9	5/8/91	7.8	0.01	29	19	3	58	98	3.14	2.3	2	1.8	2.35	0.373

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-1 (Continued)

CONCENTRATION OF CONSTITUENTS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	pH	EC	Acidity	Alka-linity	BOD_5	TSS	TDS	Total P	Cl	SO_4	NH_3-N	NO_3-N	NO_2-N
			dS/m	----------				mg/L						
9	4/22/92	6.7	0	7.0	14	5	19	29	0.56	0.8	1	0.75	0.66	0.041
9	4/9/93	6.7	0.03	3.4	91	8	21	141	5.93	19.7	6	1.91	0.7	0.028
9	11/17/93	7.2	0.07	5.8	13	<1	270	670	ND	10.9	151	6.16	1.44	0.006
9	4/12/94	6.9	0.05	5.0	41	10	14	474	2.45	4.7	149	0.64	20.35	0.039
9	12/7/94	6.9	0.07	12	46	ND	19	735	2.67	8.2	301	1.7	28	0.044
9	4/11/95	6.9	0.1	4.0	43	<1	214	890	2.51	4.2	396	0.72	20.9	0.028
10	12/9/87	6.6	0.91	45	94	16	143	12,075	4.13	682	7,570	382	1159	1.508
10	1/27/88	6.4	0.05	5.0	6	9	338	374	5.61	17	15	6.25	26.25	0.074
10	4/7/88	6.9	0.24	7.0	64	20	310	2,298	12.6	110	1,224	97.5	109.8	0.447
10	11/16/88	6.3	0.62	9.0	65	18	76	9,134	ND	218	1,944	8.5	<0.01	<0.001
10	1/26/89	6.0	0.25	18	44	14	42	2,770	1.98	75	779	5.4	<0.01	<0.001
10	4/5/89	6.2	0.57	18	39	16	15	6,317	2.13	211	1,334	5.1	747	0.315
10	7/24/89	7.0	0.46	92	26	14	11	5,026	3.57	256	602	4.55	428.5	3.64
10	1/21/90	6.9	0.33	16	69.2	27	1,024	2,890	14.1	228	858	2.61	151.5	0.11
10	5/7/90	6.8	0.28	4.0	68.4	22	58	3,344	5.92	90	1,722	1.92	194.5	0.10
10	11/28/90	6.7	0.04	25	21	15	113	251	2.04	3.9	108	0.65	6	0.048
10	3/28/91	6.6	<0.01	22	14	4	31	65	2.18	2.3	3	0.6	0.1	0.016
10	5/8/91	7.7	0.11	5.0	53	4	52	1,016	0.87	12	588	0.39	2.1	0.031
10	10/30/91	6.5	0.15	2.4	49	8	110	1,490	2.74	51.3	664	0.32	23.75	0.795
10	3/9/92	6.8	0.15	5.6	49	5	133	1,499	3.05	68.9	719	0.65	7.75	0.455
10	4/22/92	6.9	0.22	4.0	46	5	24	2,344	1.31	64.8	1,285	0.53	26.28	0.21
10	7/27/92	7.1	0.12	9.0	76	9	33	1,111	3.38	47.4	390	1.71	23.6	0.105
10	11/2/92	6.7	0.34	4.0	81	3	49	3,387	2.2	108.3	1,658	1.1	76.6	0.525
10	4/9/93	6.9	0.31	25	140	4	18	3,498	1.18	117.8	1,842	1.02	52.75	0.17
10	7/14/93	7.0	0.09	31	80	<1	6	754	1.8	15.4	349	0.49	7.05	0.043
10	11/17/93	7.1	0.13	8.0	89	<1	67	1,279	ND	29.2	676	3.01	4.95	1.15
10	4/12/94	6.2	0.09	16	17	12	26	890	0.93	28.8	417	1.45	15.52	0.092
10	4/11/95	6.7	0.11	18	31	<1	55	981	3.08	11.2	425	1.28	23.18	0.05

[1]ND = No data.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-2

CONCENTRATION OF METALS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		mg/L								
1	12/9/87	50	0.21	0.11	0.16	260	<0.02	5.24	0.4	20.1
1	1/27/88	34	0.15	0.11	0.23	492	0.49	3.06	0.4	12.1
1	4/7/88	40	0.1	0.12	0.32	822	0.65	1.95	0.2	8.5
1	1/26/89	140	0.4	0.26	0.42	854	0.13	8.78	1	39.4
1	1/21/90	26	0.1	0.06	0.09	101	<0.02	1.69	<0.1	8.2
1	5/7/90	3	0.03	0.04	0.05	18.3	<0.02	0.17	<0.1	0.8
1	11/28/90	36	0.13	0.07	0.07	122.5	<0.02	2.41	0.3	12.2
1	3/28/91	170	0.73	0.39	0.41	1,070	<0.02	12.98	1.3	68.1
1	8/14/91	124	0.42	0.21	0.43	713	<0.02	9.28	0.9	43.4
1	3/27/92	76	0.22	0.13	0.17	419	<0.02	4.89	<0.1	24.8
1	6/17/92	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
1	7/7/92	83	0.19	0.18	0.14	590	0.88	2.95	0.4	19.5
1	11/12/92	14	0.05	<0.02	0.02	62	<0.02	0.75	0.1	4.3
1	4/29/93	440	1.83	7.7	2.72	3,700	<0.02	38	3.2	190
1	4/12/94	290	0.21	0.55	1.47	8,600	25.5	5.18	1.6	25
1	12/7/94	123	0.35	0.16	0.16	785	0.11	7.54	0.8	42.8
1	4/11/95	28	0.11	0.07	0.12	193	0.17	2.05	0.3	10.4

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-2 (Continued)

CONCENTRATION OF METALS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		mg/L								
2	12/9/87	<1	0.2	0.15	0.87	1.5	<0.02	8.06	1.7	3.6
2	1/27/88	3	0.09	0.23	0.27	11.4	0.11	0.36	0.3	0.6
2	4/7/88	1	0.05	0.06	0.45	1.4	0.06	1.77	0.5	0.8
2	7/24/89	1	0.04	0.06	0.36	1.3	0.04	2.02	0.6	1
2	5/7/90	1	0.08	0.03	0.62	<0.1	<0.02	2.99	0.9	1.1
2	11/28/90	3	0.05	0.06	0.22	3.5	<0.02	1.26	0.3	0.7
2	3/28/91	1	<0.02	<0.02	0.39	0.6	<0.02	1.01	0.6	0.6
2	5/8/91	1	<0.02	0.06	0.18	1.3	<0.02	0.07	<0.1	<0.1
2	10/30/91	1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
2	3/9/92	<1	<0.02	<0.02	0.18	<0.1	<0.02	<0.02	<0.1	<0.1
2	6/18/92	<1	0.03	<0.02	0.19	0.5	<0.02	0.22	0.2	0.3
2	7/8/92	<1	0.19	<0.02	0.19	0.9	<0.02	11	<0.1	0.5
2	11/12/92	<1	0.02	<0.02	0.25	0.3	<0.02	0.1	0.3	0.5
2	4/9/93	2	0.02	<0.02	0.32	<0.1	<0.02	0.14	0.3	0.4
2	6/18/93	<1	0.04	<0.02	0.36	<0.1	<0.02	0.18	0.6	0.7
2	7/14/93	1	0.05	<0.02	0.24	<0.1	<0.02	0.15	0.05	0.8
2	11/17/93	<1	<0.02	<0.02	0.22	<0.1	<0.02	0.09	<0.1	<0.1

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-2 (Continued)

CONCENTRATION OF METALS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		mg/L								
2	5/9/96	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
3	12/9/87	2	<0.02	<0.02	0.01	<0.1	<0.02	0.2	0.1	0.3
3	1/27/88	1	<0.02	<0.02	0.16	0.3	0.08	0.26	0.2	0.4
3	4/7/88	<1	0.08	0.12	0.17	3.5	<0.02	3.55	0.6	2.9
3	11/16/88	4	0.13	0.23	0.44	46.9	0.23	3.19	0.6	3.9
3	1/26/89	1	0.05	<0.02	0.03	2.1	0.06	0.97	0.2	1.6
3	11/28/90	<1	0.13	0.03	0.14	4.8	<0.02	1.76	0.4	5.2
3	7/31/92	1	<0.02	<0.02	0.03	3.1	<0.02	<0.02	<0.1	<0.1
3	4/9/93	1	0.05	<0.02	<0.02	0.4	<0.02	0.49	<0.1	1.7
3	7/14/93	4	0.09	0.04	0.09	1.7	<0.02	0.96	<0.1	4
3	4/12/94	2	<0.02	<0.02	<0.02	4.8	<0.02	0.05	<0.1	0.7
3	4/11/95	1	0.08	<0.02	0.04	0.3	<0.02	0.75	<0.1	2.9
4	12/9/87	13	0.22	0.15	0.36	5.5	<0.02	2.49	0.5	10.4
4	12/21/87	3	<0.02	<0.02	<0.02	1.2	<0.02	0.7	<0.1	3.9
4	1/27/88	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
4	11/16/88	<1	0.05	<0.02	0.02	1.1	<0.02	0.42	0.1	1.7
4	1/21/90	2	0.03	<0.02	0.04	6	<0.02	0.23	0.1	1.3

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-2 (Continued)

CONCENTRATION OF METALS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		mg/L								
4	11/28/90	2	0.1	<0.02	0.09	1.2	<0.02	1.04	0.3	3.9
4	5/8/91	1	<0.02	<0.02	0.07	1.1	<0.02	1.23	<0.1	3.7
4	8/14/91	1	0.06	<0.02	0.05	0.6	<0.02	0.48	<0.1	2.2
4	4/22/92	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
4	7/27/92	4	0.1	<0.02	0.09	0.67	<0.02	1.07	0.13	4.26
4	11/12/92	1	0.03	0.04	0.07	2.3	<0.02	0.76	0.1	0.5
4	4/20/93	3	0.08	0.19	0.27	22.9	0.11	0.92	0.3	1.1
4	4/12/94	1	0.02	<0.02	0.07	1.3	0.07	0.14	0.1	0.1
5	12/9/87	ND[1]	ND	ND	ND	ND	ND	ND	ND	ND
5	12/21/87	1	<0.02	<0.02	0.05	4.1	0.04	0.11	<0.1	<0.1
5	1/27/88	1	<0.02	<0.02	0.05	3.2	<0.02	0.09	<0.1	<0.1
5	4/7/88	<1	<0.02	<0.02	<0.02	<0.1	<0.02	0.03	<0.1	<0.1
5	11/16/88	1	<0.02	<0.02	0.03	0.3	<0.02	0.03	<0.1	0.1
5	1/21/90	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
5	11/28/90	<1	<0.02	<0.02	0.03	<0.1	<0.02	<0.02	<0.1	<0.1
5	5/8/91	1	<0.02	<0.02	<0.02	1.6	<0.02	0.17	<0.1	0.3
5	8/14/91	1	<0.02	<0.02	0.04	0.4	<0.02	0.05	<0.1	0.2

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-2 (Continued)

CONCENTRATION OF METALS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		mg/L								
5	3/19/92	4	0.03	0.32	0.24	14.8	0.14	0.98	<0.1	0.8
5	4/22/92	<1	<0.02	0.03	0.07	0.3	<0.02	0.13	0.1	0.1
5	7/27/92	1	0.05	0.09	0.13	3.3	0.05	0.38	0.1	0.3
5	4/20/93	<1	<0.02	<0.02	<0.02	0.3	<0.02	<0.02	<0.1	<0.1
5	7/14/93	1	<0.02	0.03	0.07	1.8	<0.02	0.05	<0.1	<0.1
5	11/17/93	1	<0.02	<0.02	0.06	0.3	<0.02	<0.02	<0.1	<0.1
6	12/9/87	<1	<0.02	<0.02	0.04	<0.1	<0.02	<0.02	<0.1	<0.1
6	1/27/88	<1	<0.02	<0.02	0.04	0.4	<0.02	0.05	<0.1	0.1
6	4/7/88	1	<0.02	<0.02	0.02	<0.1	<0.02	0.03	<0.1	0.1
6	11/16/88	1	<0.02	<0.02	0.11	0.8	<0.02	0.03	0.1	0.1
6	1/21/90	<1	<0.02	<0.02	0.07	0.3	<0.02	<0.02	<0.1	0.1
6	5/7/90	1	<0.02	<0.02	0.02	0.6	<0.02	<0.02	<0.1	0.1
6	11/28/90	1	<0.02	0.06	0.08	1.8	<0.02	0.21	<0.1	0.2
6	7/27/92	1	0.03	0.04	0.08	1	<0.02	0.53	0.3	0.9
6	4/9/93	3	0.09	0.25	0.29	9.6	0.18	0.88	0.4	1.5
6	4/12/94	<1	0.02	<0.02	0.09	0.6	0.05	0.27	0.1	0.2
7	12/21/87	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-2 (Continued)

CONCENTRATION OF METALS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		mg/L								
7	1/27/88	<1	<0.02	<0.02	0.05	<0.1	<0.02	<0.02	<0.1	<0.1
7	4/7/88	1	<0.02	<0.02	0.08	0.4	<0.02	0.03	<0.1	<0.1
7	11/16/88	<1	<0.02	<0.02	<0.02	1.2	<0.02	0.03	<0.1	0.1
7	7/24/89	1	<0.02	0.05	0.05	0.6	<0.02	0.03	<0.1	<0.1
7	1/21/90	<1	<0.02	<0.02	0.04	0.3	<0.02	0.03	<0.1	0.1
7	5/7/90	1	<0.02	<0.02	0.04	1.2	<0.02	0.09	<0.1	0.2
7	11/28/90	1	<0.02	<0.02	0.04	<0.1	<0.02	<0.02	<0.1	0.1
7	7/27/92	<1	<0.02	<0.02	0.03	<0.1	<0.02	<0.02	<0.1	0.2
7	4/9/93	1	<0.02	<0.02	0.05	0.3	<0.02	<0.02	<0.1	<0.1
8	12/9/87	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
8	12/21/87	<1	0.03	0.07	0.1	0.8	<0.02	0.53	0.2	0.3
8	1/27/88	1	0.08	0.06	0.23	1.9	0.05	0.86	0.4	0.6
8	4/7/88	1	0.03	<0.02	0.08	0.5	0.11	0.1	<0.1	0.2
8	7/24/89	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
8	1/21/90	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
8	5/7/90	1	<0.02	<0.02	<0.02	0.4	<0.02	<0.02	<0.1	<0.1
8	11/28/90	1	<0.02	<0.02	0.03	0.4	<0.02	0.06	<0.1	0.2

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-2 (Continued)

CONCENTRATION OF METALS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		mg/L								
8	5/8/91	<1	<0.02	<0.02	0.02	<0.1	<0.02	<0.02	<0.1	0.1
8	4/22/92	1	<0.02	<0.02	0.07	0.5	<0.02	0.03	<0.1	0.4
8	7/31/92	1	<0.02	0.08	0.08	3.2	<0.02	0.28	<0.1	0.2
8	4/20/93	<1	0.02	0.02	0.06	0.2	<0.02	0.23	0.1	0.1
8	11/17/93	5	0.09	0.21	0.31	13.3	0.13	0.59	0.3	0.6
8	4/12/94	2	0.02	0.02	0.09	1.9	0.05	0.06	<0.1	<0.1
8	4/11/95	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
9	12/9/87	1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
9	1/27/88	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
9	4/7/88	1	<0.02	<0.02	0.08	0.3	<0.02	0.03	<0.1	<0.1
9	11/16/88	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
9	1/26/89	<1	<0.02	<0.02	0.03	<0.1	<0.02	<0.02	<0.1	<0.1
9	7/24/89	2	0.03	0.11	0.12	6.1	0.02	1.05	<0.1	0.7
9	1/21/90	<1	0.05	0.03	0.18	1.1	<0.02	0.92	0.4	1.1
9	5/7/90	3	0.09	0.14	0.34	10.2	0.11	0.89	0.4	0.9
9	11/28/90	1	0.02	0.02	0.16	0.6	0.04	0.11	0.1	0.2
9	4/22/92	1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-2 (Continued)

CONCENTRATION OF METALS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		mg/L								
9	4/9/93	1	<0.02	<0.02	0.05	0.6	<0.02	<0.02	<0.1	<0.1
9	11/17/93	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
9	4/12/94	1	<0.02	<0.02	0.05	<0.1	<0.02	<0.02	<0.1	<0.1
9	12/7/94	<1	<0.02	<0.02	0.03	0.4	<0.02	<0.02	<0.1	<0.1
9	4/11/95	<1	<0.02	<0.02	<0.02	1.1	<0.02	0.06	<0.1	0.1
10	12/9/87	1	<0.02	<0.02	0.08	1	<0.02	0.1	0.1	0.2
10	1/27/88	<1	<0.02	<0.02	0.02	1	<0.02	<0.02	<0.1	0.1
10	4/7/88	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
10	11/16/88	1	<0.02	<0.02	0.05	<0.1	<0.02	0.09	0.2	0.3
10	1/26/89	<1	<0.02	<0.02	0.13	0.6	<0.02	0.05	0.1	0.1
10	4/5/89	1	<0.02	<0.02	0.1	<0.1	<0.02	0.05	<0.1	0.1
10	7/24/89	3	0.1	0.44	0.64	9.1	0.11	2.72	0.6	1.7
10	1/21/90	10	0.2	1.32	1.29	29.5	0.55	1.95	0.7	2.6
10	5/7/90	2	0.02	0.06	0.21	1.6	0.06	0.21	0.2	0.1
10	3/28/91	1	<0.02	0.08	0.16	2	0.05	0.17	<0.1	<0.1
10	5/8/91	<1	<0.02	<0.02	0.06	<0.1	<0.02	<0.02	<0.1	<0.1
10	10/30/91	1	<0.02	<0.02	0.04	<0.1	<0.02	<0.02	<0.1	<0.1

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE AIII-2 (Continued)

CONCENTRATION OF METALS IN SURFACE WATER RUNOFF FROM TEN PLOTS ON ST. DAVID COAL REFUSE PILE AMENDED WITH BIOSOLIDS AND BIOSOLIDS + LIME

Plot Number	Sample Date	Al	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		mg/L								
10	3/9/92	<1	<0.02	<0.02	0.03	<0.1	<0.02	<0.02	<0.1	<0.1
10	4/22/92	1	<0.02	0.03	0.14	0.6	<0.02	0.03	<0.1	<0.1
10	7/27/92	<1	<0.02	<0.02	0.07	<0.1	<0.02	<0.02	<0.1	<0.1
10	11/2/92	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
10	4/9/93	<1	<0.02	<0.02	<0.02	0.3	<0.02	0.03	<0.1	<0.1
10	7/14/93	<1	<0.02	<0.02	<0.02	<0.1	<0.02	<0.02	<0.1	<0.1
10	11/17/93	1	<0.02	<0.02	0.03	<0.1	<0.02	0.09	0.1	0.1
10	4/12/94	<1	<0.02	<0.02	0.13	<0.1	<0.02	0.03	0.1	0.1
10	4/11/95	2	<0.02	<0.02	0.14	2.5	0.05	0.06	0.1	0.3

[1]ND = No data.