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Report to

NERCO Inc.
111 S.W. Columbia Suite 800
Portland, Oregon 97201

Submitted by

Utah State University Foundation
Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

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INTRODUCTION

Scrubber wastes obtained in an effort to limit air pollution generated by coal-fired power plants may contribute to another possible source of pollution. To date, scrubber wastes have been in a liquid phase which causes disposal problems partially due to the liquid characteristics. The use of solid scrubber wastes and the land deposition of such wastes is proposed. The feasibility of solid scrubber wastes disposal in landfills is under question. The primary area of concern is the effect that water percolation through such wastes would have on groundwater quality parameters. Contamination could result either as preciptiation travels downward through the wastes and into the water table or as the water table rises into the scrubber wastes and then retreats. Groundwater contamination is a key concern because it is largely irreversible and has long term consequences.

OBJECTIVE

Disposal methods for coal-fired power plant fly ash and scrubber wastes present a potential for the contamination of groundwater aquifers. In this study the general objective was to evaluate the physical and chemical characteristics of the leachates of scrubber wastes and associated disposal materials separately and in appropriate combinations using laboratory bench scale techniques. Two approaches, namely column leaching and batch elutriation, were developed and used to provide indicators characteristic of the materials tested.

LITERATURE REVIEW

Literature available and presented in this review on the subject of scrubber waste deals almost exclusively with the fly ash component. It should be relevant to the question of scrubber waste disposal due to the high percentage of fly ash in the waste. Previous studies concerning disposal options, the physical and chemical characteristics of fly ash, the chemical nature of fly ash leachates and the behavior of leachates in the environment are presented.

Fly ash particles have been found to provide the most important mode of transport for trace elements entering the environment as a result of coal combustion (Andren et al. 1980). Past and present disposal practices for coal combustion wastes include ponding and landfilling. Problems resulting from these procedures include contamination of groundwater through percolation of precipitation through the waste. Low permeability clay-lined ponds have been provided at some of the more recent installations (Jones 1977). Ocean disposal of the waste has major impacts on the marine environment. Increased suspended solids in the water, toxic effects due to sulfite mobilization, ocean floor sedimentation and trace element contamination are some of the hazards related to ocean disposal (Jones 1977). Currently, this disposal method is not legal in the coastal waters of the United States. Disposal of waste in abandoned underground mines has been considered but not utilized due to the generally close contact which would result between the waste and groundwater (Santhanam et al. 1980).

Fly ash is quite variable in composition. Power plant configuration has been found to govern the type and amount of elements and compounds in the resultant ash (Page et al. 1979). The type of coal used also greatly effects the composition of fly ash. Low sulfur coals of the western United States have been found to contain lower levels of trace metals in general (Theis and Wirth 1977). Al, Si, Ca, Fe, Mg, Na, K, S, Ba, and Sr are the elements which dominate the fly ash matrix in addition to numerous trace elements. Largely volatile elements such as Hg, Se, Sb, As, Cl, F, and I are concentrated in the fly ash (Page et al. 1979). The furnace environment is thought to favor oxide formation of the metals in question. Therefore, most of the elements contained in fly ash exist in an oxide form. Additionally, silicates, sulfates, and borates are formed along with smaller amounts of phosphates and carbonates (Plank and Martens 1973). Fly ash is therefore primarily classified as an amorphorus ferro-alumino silicate mineral.

Fly ash consists of many small (0.01-100 m diameter) glass like particles. Page et al. (1979) found As, Be, Cd, Co, Cr, Cu, Ga, Mn, Mo, Ni, Pb, Sb, Se, U, V, W, and Zn increased with decreasing particle size but Theis and Wirth (1977) could not substantiate these findings.
The leachability of elements from fly ash has been found to be related to the element's position in the fly ash matrix. On the basis of matrix position alone, elements such as Fe, Si, Ba, Ca, and Mg should exhibit low extractability. Elements which predominate in the surface layer including Cd, Co, Li, Mn, P, Tl, and Zn should exhibit substantial extractability (Page et al. 1979).

Leachates emanating from scrubber wastes, particularly the fly ash component, have been characterized in a number of studies. There is a high degree of variability in leachate composition depending on the coal used and power plant configuration among other variables. Measurable quantities of Ca, Cl, Na, SO_4, F, Sb, As, Be, B, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Ni, Se, and Si have been observed in scrubber waste leachates (Santhanam et al. 1980). Fly ash from low sulfur coal combustion results in very alkaline leachates (pH 10-12) due to amorphous lime oxides on the surface of fly ash particles (Theis and Wirth 1977). It has been found that aluminum, iron, and silica are particularly soluble at elevated pH values (Andren et al. 1980). Elements which form anionic species such as B, Mo, F, Se, Cr, and V remain relatively soluble under alkaline conditions while metallic cations would be expected to precipitate (Page et al. 1979). Theis and Wirth (1977) found that lead, although relatively insoluble, is released to a greater extent than any other soluble species. Arsenic which is known to form precipitates with many trace metals, especially iron, exhibits a sudden increase at pH 12 probably due to the unavailability of free metal ions. Most trace metals displayed slight increases in release at high pH (Theis and Wirth 1977). Leaching of boron has been found to be independent of pH (Cox et al. 1978).

It is still questionable whether pH of the extractant governs the chemical composition of the resultant leachate. Column leaching tests performed for the EPA suggest that no significant variation of leachate quality with pH exists (Santhanam et al. 1980). Other studies have shown substantial differences due to the pH of the extraction solution. Page et al. (1979) observed an increase in the extractability of all elements as the acidity of the extract was increased (Page et al. 1979). Phung et al. (1979) reported the concentrations of B, Pb, Co, Cr, and Ni increased as the pH of the fly ash suspension was lowered from 12 to 9. Additionally, further releases of trace elements resulted as pH was lowered to 6. It was found that Cu and Cd were least affected by pH changes (Phung et al. 1979). The majority of studies conducted suggest that the pH of the extractant does affect the chemical composition of the leachate.

Attenuation of a fly ash leachate as it percolates through the soil and enters the groundwater system has been reported in a number of studies. In general, three attentuation mechanisms are operative in leachate/soil and leachate/groundwater interactions including formation of insoluble precipitates, ion exchange, and adsorption onto local solid phases (Theis et al. 1978). There are a number of variables involved in the degree to which attenuation will occur including soil characteristics and the chemical composition of the groundwater. The primary adsorption process occurring in the soil over time is due to iron, aluminum, and manganese oxides present in the coating on fly ash particles (Andren et al. 1980).

Theis and Richter (1979) using an adsorption model predict that as the leachate enters the soil environment, Zn, Cd, and Ni are attenuated predominately by adsorption onto iron and manganese oxides. The solubilities of chromium, copper and lead are controlled by discrete precipitates while adsorption is of diminished importance. Copper should precipitate as the basic carbonate. When inorganic carbon concentrations increase due to the presence of natural groundwater, the model predicts lead carbonate will form. The sulfate ion forms weak complexes with all metals studied. The solution pH was determined to be a variable which brings about the most noticeable changes in soluble metals, affecting the extent of adsorption and degree of precipitation. The purposeful use of oxides for heavy metal attenuation depends upon maintaining an oxidizing soil environment (Theis and Richter 1979).

The chemical behavior of a scrubber waste and/or fly ash leachate in the environment is highly variable. Hydrologic characteristics of the disposal site are of considerable importance in assessing the movement of leachates into and through a groundwater system. The rate of leachate migration will depend on the hydraulic conductivity of the subsurface stratum in addition to the degree of attenuation which occurs. Composition of the aquifer will impact leachate migration. A sandy stratum will provide little attenuation (Milligan and Ruane 1979). Groundwater pH is usually lower than the leachates resulting from western United States coal combustion wastes and the therefore leachates entering the groundwater environment are expected to release some fraction of the trace elements (cations) to the dissolved phase. The organic matter present in receiving waters will tend to solubilize trace metals such as Cd, Cu, Pb, and Zn by chelation and complexation reactions (Andren et al. 1980).

Most studies of groundwater contamination around fly ash disposal sites are inconclusive due to insufficient monitoring time. Testing of groundwater around a fly ash disposal site using wells determined boron concentrations to be the greatest in the well farthest from the disposal area. Data from the project indicate that groundwater concentrations are neither spatially nor temporally consistent with that expected from waste loading on the surface (Andren et al. 1980). Highly variable concentrations of Ca, SO_4, alkalinity, Pb, and Mg in groundwater samples collected in the vicinity of another ash disposal area have been reported but these values were consistently higher overall as compared to samples collected away from the ash disposal area (Milligan and Ruane 1979). The primary variable in the degree of groundwater contamination appears to be the path length of the seepage water (Theis et al. 1978). It has been suggested that possible deleterious effects of leachate percolation could be reduced through the use of disposal ponds lined with clay thereby encouraging attenuation of the leachate and greatly reducing permeability (Jones 1977).

METHODS AND PROCEDURES

Leachate Methods and Experimental Design

Coal-fired power plant scrubber waste leachate was generated by two methods. Upflow columns were primarily used, and some batch elutriation experiments were performed. For both methods, dry scrubber waste, coal, topsoil, and overburden were handled similarly, prior to contact with experimental waters. The study was carried out during the period August through December, 1981.

The column technique for developing leachate appears to be a better model of environmental conditions than the batch elutriation method. For this study, the cylindrical columns were constructed of high quality borosilicate glass; the overall column size was 61 cm (24 in.) in length and 7.6 cm (3 in.) in inner diameter. The columns had a stopcock and micro valve at the lower end to control flow rate; the flow velocity was maintained near 10^{-4} cm/sec. To avoid various problems associated with gravity drainage columns (plugging, air entrapment, etc.), the columns and test waters were set up to allow for upflow (see Figure 1). Upflow columns have been shown to generate relatively reproducible leachate media (DiNovo 1975; Maase et al. 1975; Cleave 1979; Maase 1980; Adams 1979). The column technique was used in three facets of this project. The first was to evaluate site-collected groundwater through various column materials (overburden, scrubber waste, etc.) in sequential 10-day experiments. The second was to evaluate laboratory doubly deionized water (Milli-Q reagent grade) through column materials in sequential 10-day experiments. The third used groundwater or doubly

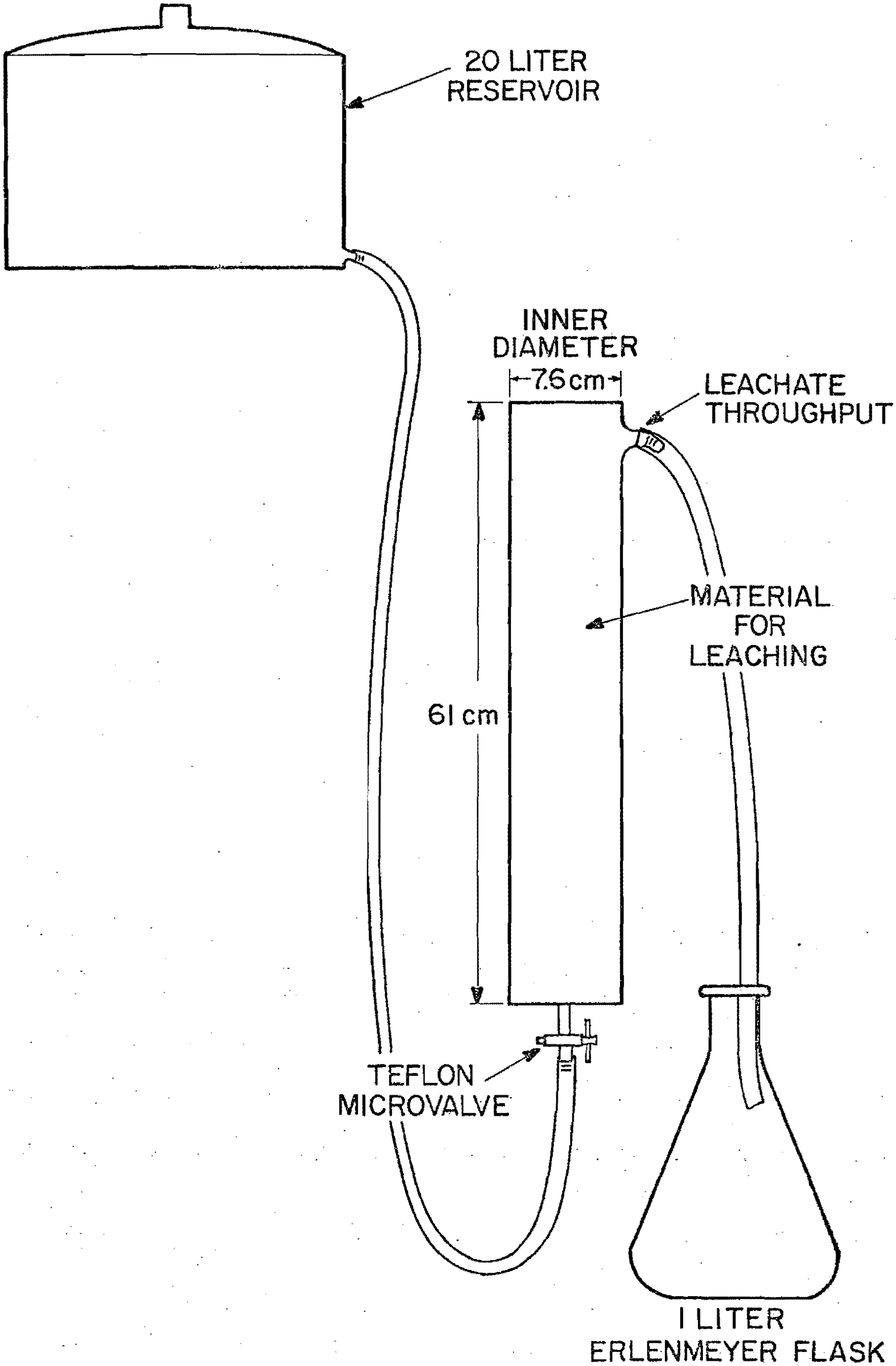


Figure 1. The upflow column for leaching topsoil, coal, overburden, and scrubber wastes (adapted from Adams, 1979).

deionized water through one set of columns, using materials of topsoil, coal, and scrubber wastes. Table 1 lists the dry materials used. Schematic diagrams of the experimental designs are shown in Figures 2 and 3. Photograph 1 shows four upflow columns packed with scrubber wastes, topsoil and coal using groundwater as the leachate media.

Column materials were weighed with a top-loading laboratory balance, using 2200 grams of air-dried material per column for all column materials except coal. This quantity of coal could not be packed into a column due to the lower density of the coal. Table 1 lists the weights of column materials used corrected to the oven-dried (103°C) weight. For the experiments with columns run in sequence (Figure 3, A and B), the columns for all levels of the tiers except the last were set up in replicate in order to generate enough leachate for the following set of columns. The flow velocity was set on each column near 10^{-4} cm/sec, giving a final leaching volume of 1 ℓ/column/day. The leachate for each column was

Table 1. Dry materials used; oven-dry corrected weights.

Dry Materials	Weight per Column, g (Corrected to Oven-Dry Weight)
Topsoil	2190
Overburden, 081043	2169
Overburden, 081044	2181
Calcium Scrubber Waste and Ash	2188
Sodium Scrubber Waste and Ash	2103
Coal 1. (DDW → Coal)	1811
2. (Groundwater → Coal)	1721

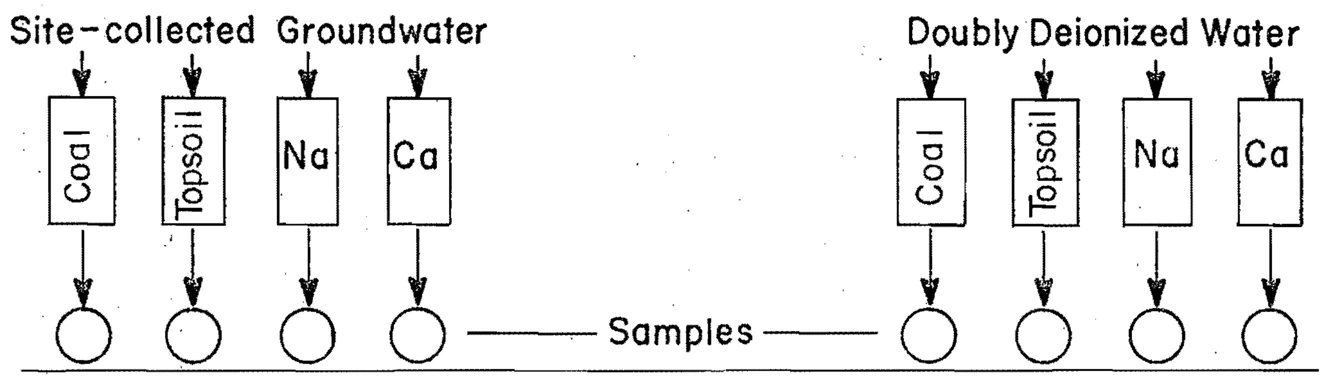


Figure 2. Single-column leaching experimental design.

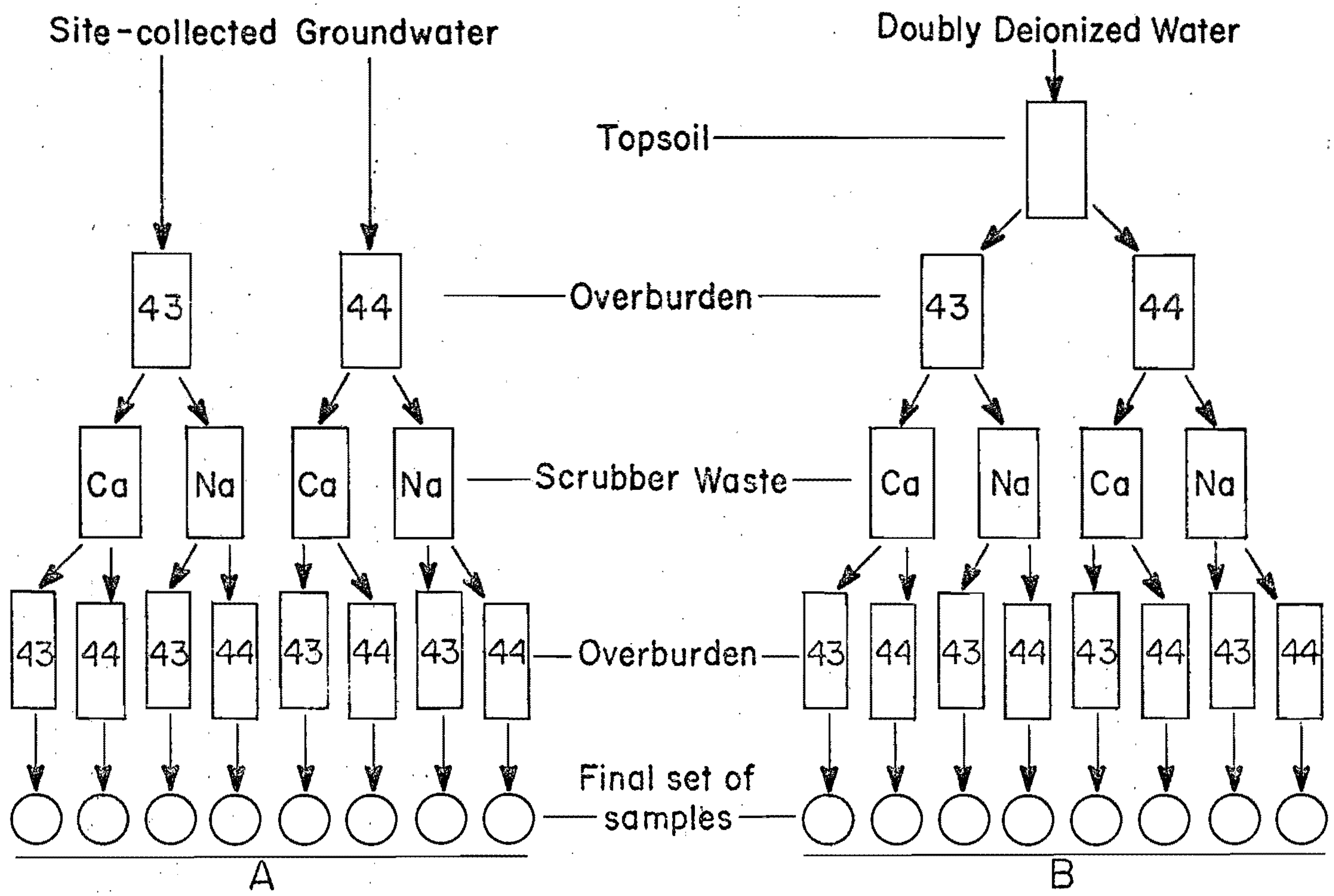
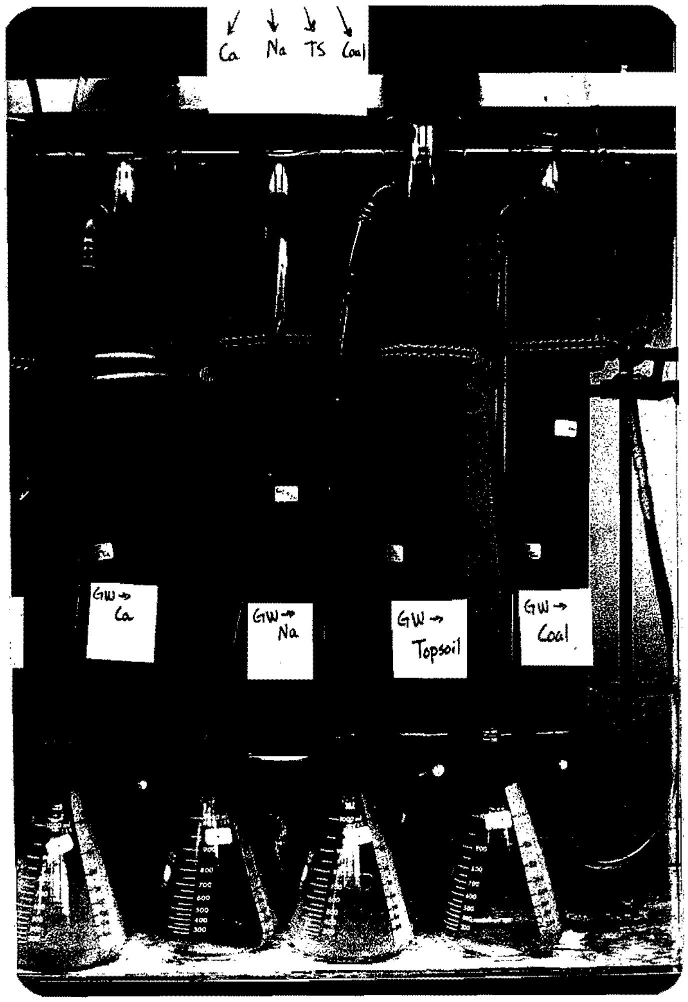


Figure 3. Sequential-column leaching experimental design.



Photograph 1. Upflow columns from part of the single-column experiment. Dry materials of calcium scrubber waste, sodium scrubber waste, topsoil and coal with groundwater as the leaching media.

collected in a 1-liter Erlenmeyer flask. Each day the sample water was poured off, filtered through a 0.45 μm glass fiber filter, and the water from the replicate columns was mixed together. Of this mixture, 500 to 1000 ml was saved each day for immediate analysis and the remainder was stored in glass containers or teflon-lined barrels at 5°C to be used for the succeeding set of columns. Each set of columns was allowed to run for a proposed time of 10 to 12 days. In a few cases, the columns ran for only 8 or 9 days, if the water available was limited.

For the sequential columns (Figure 3, A and B), the water saved from the preceding set of columns was thoroughly mixed and then used as the test water. In this way, the test water for any given set of columns in the tier was a composite of the leachate from all 10 days of the corresponding previous set of columns.

The batch elutriation method involves mixing known masses of dry materials with test waters for a specified period of time. Relative mix concentrations, mixing environment energies, and mixing duration are being standardized to allow immediate comparison of literature reported elutriation values (Keeley and Engler 1974; Reimer 1975; Cleave 1979). The dry materials used in the batch elutriation study were topsoil, two types of overburden, calcium based scrubber waste plus ash mixture, and sodium based scrubber waste plus ash mixture. Three test waters were added to these materials resulting in 15 distinct types of leachate. The test waters included site-collected groundwater (GW), laboratory doubly deionized water (DDW), and doubly deionized water acidified with nitric and sulfuric acids to an approximate pH of 4. The combinations of dry materials and test waters are listed in Table 2. For each type of leachate, 250 ml of the test water was added to 25 g of air-dried, dry material in an Erlenmeyer flask; each was set up in triplicate for a final leachate volume of 750 ml. The flasks were agitated on a laboratory shaker table at 150 rpm for 48 hours. The samples were allowed to settle for 1 hour and then filtered through 0.45 μm glass fiber filters.

Table 2. Batch elutriation leachate.

Topsoil plus DDW
Topsoil plus groundwater
Topsoil plus acidic DDW
Calcium scrubber waste and ash plus DDW
Calcium scrubber waste and ash plus groundwater
Calcium scrubber waste and ash plus acidic DDW
Sodium scrubber waste and ash plus DDW
Sodium scrubber waste and ash plus groundwater
Sodium scrubber waste and ash plus acidic DDW
Overburden 43 plus DDW
Overburden 43 plus groundwater
Overburden 43 plus acidic DDW
Overburden 44 plus DDW
Overburden 44 plus groundwater
Overburden 44 plus acidic DDW

Dry Materials and Test Waters

The dry materials used in the upflow column and batch elutriation methods included topsoil, coal, calcium-based scrubber waste, sodium-based scrubber waste, and overburden of two types. All materials were obtained from the Jim Bridger Coal Company site near Rock Springs, Wyoming. All materials were shipped or otherwise transported to the Utah Water Research Laboratory in Logan, Utah. The topsoil was sieved using a 20 mesh/in. standard sieve. The coal was crushed and sieved through a 20 mesh/in. sieve. The scrubber wastes were used as received; the mixtures of scrubber wastes and ash were prepared at the plant in proportions suitable for disposal (Knight, personal communication, 1981). The overburden samples were obtained as core samples identified as 081043 and 081044. All references to the overburden types in the results and data tables include the core number or a shortened form (43 or 44). The core samples were drilled to approximately 80 feet and were shipped in 1 to 2 foot sections, with labels. For core #081043, sample totaling approximately 16 feet was missing; approximately 20 feet of core #081044 was missing. For both cores, the sample was deleted due to one of several reasons including 1) coal seams omitted from shipment or 2) sample apparently lost or missing during the field drilling. These cores were obtained using an on-site pond water; a sample of this pond water was sent to the Utah Water Research Laboratory and was analyzed. It is listed in Table 13 as "core water." The overburden samples were crushed and sieved (20 mesh/in.) in 1 foot sections. For each core, equal amounts from each 1 foot section were mixed together to generate the overburden sample ready for use in the columns or the elutriation tests. Percent moisture was performed on all dry test materials, using an analytical balance and a 103°C oven.

The test waters included groundwater collected from the Jim Bridger Coal Company site near Rock Springs, Wyoming, and laboratory doubly deionized water. The groundwater was collected by Jim Bridger personnel and shipped to the Utah Water Research Laboratory. The water was shipped in several containers and was mixed together in a teflon-lined 55 gal drum before use. The water was stored at 5°C to minimize changes in the composition of the water. An inadequate amount of groundwater was shipped initially requiring Utah Water Research Laboratory personnel to visit the Jim Bridger site to collect more groundwater. This resulted in groundwater of a somewhat different composition used for the first set of groundwater-through-overburden columns. The groundwater collected in October was obtained in a teflon-lined 55 gal drum and in several smaller containers. It was stored for the duration of the study at 5°C. After the completion of the first groundwater series of columns, the batch elutriation tests were carried out. At this time, another composited mixture of groundwater was used from the smaller containers. A last mixture of groundwater was used in December, for the final set of groundwater columns (groundwater through topsoil, coal, and scrubber wastes). Table 3 lists the dates of groundwater analyses and uses in the experimental design. These dates are also referred to in the data tables. The laboratory doubly deionized water is a reagent grade type of water. It is obtained in the Utah Water Research Laboratory by passing tap water through a standard set of cation-anion exchange columns (Culligan brand) and then through a mixed-bed set of cation-anion exchange columns (Milli-Q system, by the Millipore Corporation). The resulting doubly deionized water is a high quality water with resistance of 10 to 18 megaohms. The acidic water used in the batch elutriation study was prepared by mixing equal amounts of concentrated nitric and sulfuric acids and adding the mixed acids to doubly deionized water. Approximately one drop of mixed concentrated acid per liter of doubly deionized water was required to lower the pH to approximately 4.

Table 3. Groundwater uses.

Date	Use in Experimental Design
8 Sept 81	1st half: groundwater through overburden (Fig. 3A)
9 Oct 81	2nd half: groundwater through overburden (Fig. 3A)
30 Nov 81	Batch elutriation
28 Dec 81	Groundwater through topsoil, coal, scrubber wastes

Analysis Schedule and Analytical Methods

The chemical parameters analyzed in this study are listed in Table 4. During most of the study, pH and conductivity (EC) were measured everyday. For other constituents, samples were analyzed from the first day's leachate, and then from composited two-day volumes.

The Water Quality Laboratory at the Utah Water Research Laboratory (UWRL) is a USEPA and Utah certified laboratory and follows the guidelines for quality control suggested by the USEPA and the State of Utah. This includes using specific procedures in analyses, using quality control samples, and performing some analyses in replicate. For all tests used in the UWRL Water Quality Laboratory, standard curves, standardized titrants, and/or calibrated instruments are always used.

The specific methods used in analysis of the parameters are given in Table 4. Standard curves were always generated, for the analysis of metals by atomic absorption spectrophotometry, and the linear regression of the standard curve determined the detection limit on that day of analysis.

Values for input leaching media are listed in the data tables. This "weighted mean" input media was calculated using the total volume of leachate produced on a given day in the sequential column scheme minus the sample volume used for the analyses.

Table 4. Chemical parameters.

Parameter	Method	Reference
pH	Potentiometric, Electrode	APHA, 1980, p. 402
EC	Conductrimetric	APHA, 1980, p. 70
Temperature	Calibrated Thermometer	APHA, 1980, p. 124
Total Dissolved Solids	Gravimetric	APHA, 1980, p. 92
Total Alkalinity	Titrimetric	APHA, 1980, p. 253
Chloride	Mercuric Nitrate Titrimetric	APHA, 1980, p. 271
Fluoride	SPADNS Colorimetric	APHA, 1980, p. 337
Sulfate	Turbidimetric	APHA, 1980, p. 439
Nitrate	Automated Cadmium Reduction Plus Diazotization Colorimetric Method	APHA, 1980, p. 376
Nitrite	Automated Diazotization Colorimetric	APHA, 1980, p. 376
Calcium	EDTA Titrimetric	APHA, 1980, p. 185
Magnesium	EDTA Titrimetric	APHA, 1980, p. 195
Arsenic	Atomic Absorption, Hydride Generation	APHA, 1980, p. 160
Boron	Carmine Colorimetric	APHA, 1980, p. 260
Beryllium	Atomic Absorption, Flame	APHA, 1980, p. 157
Cadmium	Atomic Absorption, Flame	APHA, 1980, p. 152
Chromium	Atomic Absorption, Flame	APHA, 1980, p. 152
Copper	Atomic Absorption, Flame	APHA, 1980, p. 152
Lead	Atomic Absorption, Carbon Furnace	APHA, 1980, p. 166
Mercury	Atomic Absorption, Cold Vapor	APHA, 1980, p. 164
Nickel	Atomic Absorption, Flame	APHA, 1980, p. 152
Selenium	Atomic Absorption, Hydride Generation	APHA, 1980, p. 160
Zinc	Atomic Absorption, Flame	APHA, 1980, p. 152

RESULTS AND DISCUSSION

Column Leaching

Single Column Leaching of Topsoil, Coal, Na Scrubber Wastes and Ca Scrubber Wastes Using Doubly Deionized Water (DDW) and Groundwater (GW)

Following the methods and procedures as previously described (also see Figure 2) 2200 grams of air dried topsoil, Na scrubber wastes and Ca scrubber wastes were packed into individual glass columns and leached with DDW or GW for 10 days at an approximate throughput rate of 1 ℓ/day. Only 2000 grams and 1900 grams of coal were used for DDW and GW leaching respectively due to the coal's low density and the column capacity. The results are shown in Tables 5-12. The pH of the leachate from the scrubber wastes are consistently higher than the pH of the leachate from the topsoil and the coal. The highest pH was 12.7 for the Ca scrubber wastes with the highest pH of 11.6 being observed from the Na scrubber wastes. The conductivity of the leachate material changing with time is shown in Figure 4. The initial conductivities of the DDW and GW Na scrubber leachate were 65,200 μmhos/cm and 60,800 μmhos/cm respectively decreasing to 8820 μmhos/cm and 14,800 μmhos/cm. The Ca scrubber wastes showed similar trends but at lower conductivity levels. The conductivity (EC) of the DDW leachate of the topsoil and coal showed a decreasing trend whereas conductivity of the GW leachate remained essentially the same as the initial conductivity of the GW (Table 13). Total dissolved solids (TDS), total alkalinity, chloride, sulfate, sodium, fluoride, copper, boron, selenium follow trends similar to the conductivity data

Table 5. Single column experiment data: DDW → topsoil.

DDW → Topsoil

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	8.2	682	968	29	25	0.7	244	1.3	0.1	69	22	47	15	0.20	<14	<4	<10	13	<1	1.0	<11	13	13
2	8.0	810																					
3	8.0	730																					
Comp 2+3			512	32	14	1.0	271	1.5	0.1	73	17	52	18	0.19	<14	<4	<10	15	<1	6.0	<11	44	24
4	8.1	632																					
5	8.4	307																					
Comp 4+5			316	44	13	1.1	141	0.8	0.1	44	11	30	15	0.19	<14	<4	<10	13	<1	8.0	<11	3	11
6	8.5	268																					
7	8.5	231																					
Comp 6+7			158	44	4	0.8	62	0.2	<0.1	28	5	<18	16	0.18	<14	<4	<10	9	<1	0.2	<11	13	19
8	8.4	145																					
9	8.4	113																					
Comp 8+9			96	41	2	0.7	24	0.1	<0.1	16	5	<18	15	<0.10	<14	<4	<10	<7	<1	0.5	<11	8	22
10	8.4	113																					
11	8.4	122																					
Comp 10+11			84	46	1	0.6	22	<0.1	<0.1	16	8	4	17	0.12	<14	<4	<10	<7	<1	<0.2	<11	5	18

DDW: Doubly deionized water
Comp: Composite sample.

Table 6. Single column experiment data: DDW → coal

DDW → Coal

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	6.7	1,970	1,694	80	5	4.8	952	1.0	<0.1	198	161	29	6	6.14	<14	<4	<10	<7	4	0.2	<11	90	10
2	7.8	598																					
3	7.8	243																					
Comp 2+3			304	82	1	3.4	82	0.28	<0.1	28	26	<19	5	6.04	<14	<4	<10	13	<1	0.3	<11	66	<5
4	7.2	205																					
5	7.3	200																					
Comp 4+5			148	64	2	3.8	20	0.04	<0.1	18	10	<19	17	4.92	<14	<4	<10	10	<1	<0.2	<11	22	29
6	7.8	141	*	60	1		25	<0.04	<0.1	9	7	<19	19	4.16	14	<4	<10	7	<1	<0.2	<11	44	28
7	7.9	157																					
8	7.8	137																					
Comp 7+8			182	54	1	1.5	16	0.04	<0.1	11	8	<19	11	2.58	<14	<4	<10	9	<1	<0.2	<11	37	10
9	7.6	153																					
10	8.3	137																					
Comp 9+10			132	48	1	1.3	1.7	<0.04	<0.1	15	8	<18	21	2.45	<4	<5	<9	<16	<1	0.2	<9	13	<6

*Insufficient sample.

DDW: Doubly deionized water
Comp: Composite sample.

Table 7. Single column experiment data: DDW → Ca SW.

DDW → Ca SW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.3	17,100	8,303	3,180	209	9.7	2,120	13.7	16.3	915	<1	303	21	56.0	14	<4	498	18	<1	0.9	<11	182	29
2	12.3	18,200																					
3	12.2	8,980																					
Comp 2+3			5,675	3,310	109	8.7	1,690	9.9	10.1	933	12	949	25	45.7	15	<4	650	34	4	0.2	<11	143	16
4	12.7	8,900																					
5	12.2	7,760																					
Comp 4+5			2,610	2,070	17	6.9	243	0.8	1.5	917	<1	65	19	1.25	15	5	270	23	1	0.3	<11	82	9
6	12.3	7,450	1,380	1,850	10	2.3	166	0.2	1.0	612	6	35	22	1.76	<14	<4	98	19	3	0.2	<11	43	5
7	12.2	6,400																					
8	12.4	5,360																					
Comp 7+8			*	1,340	11	2.6	39	0.1	0.5	442	<1	<19	24	0.21	<14	<4	47	19	<1	<0.2	<11	61	25
9	12.7	6,000																					
10	12.1	4,530																					
Comp 9+10			1,198	1,120	14	1.8	15	<0.1	0.4	435	19	<18	23	<0.10	<4	<5	21	19	5	0.6	<9	19	<6

*Insufficient sample.

DDW: Doubly deionized water
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 8. Single column experiment data: DDW → Na SW.

DDW → Na SW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.4	65,200	92,470	27,100	635	183	39,500	37.3	22.7	42	110	32,300	1760	138	14	<4	554	325	<1	6.2	15	2280	52
2	9.7	49,800																					
3	10.0	42,300																					
Comp 2+3			49,550	16,300	527	120	20,200	25.5	14.5	24	28	17,400	900	118	16	5	350	129	<1	2.2	<11	1540	12
4	10.6	35,500																					
5	10.6	24,000																					
Comp 4+5			27,380	10,200	263	155	9,350	11.0	9.0	15	9	8,370	820	75.6	14	<4	240	59	<1	1.6	<11	613	14
6	11.0	18,600	14,800	5,150	148	48	5,290	6.4	5.1	6	5	3,680	450	47.0	<14	<4	151	29	<1	0.7	<11	306	9
7	11.0	14,200																					
8	11.6	11,100																					
Comp 7+8			9,052	3,360	93	41	2,770	4.2	3.3	5	3	1,430	270	35.4	<14	<4	104	21	<1	0.4	<11	245	5
9	11.6	8,700																					
10	11.4	8,820																					
Comp 9+10			5,906	2,400	59	38	2,340	2.8	2.2	6	7	715	130	23.4	<4	<5	49	22	13	0.5	<9	102	<6

DDW: Doubly deionized water
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 9. Single column experiment data: GW → topsoil.

GW → Topsoil

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	8.1	3,680	*	675	41	1.6	1,230	1.5	0.1	71	29	757	17	10.8	<4	<5	<9	20	<1	<0.2	<9	14	<6
2	8.2	4,310																					
3	8.4	4,110																					
Comp 2+3			2,996	662	75	2.4	1,600	2.5	1.3	152	53	778	14	1.19	<4	<5	11	26	2	<0.2	<9	9	<6
4	8.1	3,830																					
5	8.1	3,880																					
Comp 4+5			2,784	737	47	1.7	1,480	1.2	0.6	119	50	728	6	0.93	<4	<5	13	26	<1	4.9	<9	12	<6
6	8.2	3,490																					
7	8.4	3,620																					
Comp 6+7			2,540	725	35	2.1	1,310	1.5	0.1	75	31	718	24	1.30	<4	<5	11	23	5	0.4	<9	16	<6
8	8.5	3,520																					
9	8.5	3,610																					
Comp 8+9			2,443	737	33	1.5	1,180	1.1	0.2	45	28	746	27	0.97	<4	<5	<9	20	1	<0.2	<9	12	<6
10	8.5	3,560	2,423	735	32	1.4	1,170	1.6	0.1	40	26	764	25	0.80	<4	<5	<9	18	4	0.2	<9	18	<6
INPUT**	8.4	3,770	2,521	754	32	1.1	1,130	1.2	<0.1	57	32	773	2	0.89	<4	<5	9	27	6	<0.2	<9	16	860

*Insufficient sample.
**Groundwater (28 Dec. 1981)

GW: Groundwater
Comp: Composite sample.

Table 10. Single column experiment data: GW → coal.

GW → Coal

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	7.7	3,480	*	148	37	4.1	1,860	1.4	<0.1	324	228	237	27	6.33	<4	<5	15	27	<1	2.0	<9	20	10
2	7.3	2,950																					
3	8.3	3,150																					
Comp 2+3			2,262	306	36	4.3	1,410	1.0	<0.1	146	98	435	24	5.80	<4	<5	17	18	<1	<0.2	<9	15	<6
4	7.6	3,200																					
5	7.5	3,300																					
Comp 4+5			2,286	499	39	1.0	1,230	<0.1	<0.1	78	47	589	24	4.15	<4	<5	<9	21	<1	7.4	<9	17	13
6	7.7	3,140																					
7	7.8	3,380																					
Comp 6+7			2,314	512	32	2.4	1,280	<0.1	<0.1	62	27	654	23	3.54	<4	5	<9	24	2	6.7	<9	14	8
8	8.0	3,470																					
9	8.3	3,420																					
Comp 8+9			2,358	532	33	1.2	1,180	<0.1	<0.1	47	23	697	27	2.67	<4	<5	<9	21	<1	<0.2	<9	14	<6
10	8.2	3,440	2,367	541	33	0.5	1,110	0.2	<0.1	19	12	730	20	2.37	<4	<5	<9	19	<1	<0.2	<9	19	<6
INPUT**	8.4	3,770	2,521	754	32	1.1	1,130	1.2	<0.1	57	32	773	2	0.89	<4	<5	9	27	6	<0.2	<9	16	860

*Insufficient sample.
** Groundwater (28 Dec. 1981)
GW: Groundwater
Comp: Composite sample.

Table 11. Single column experiment data: GW → Ca SW.

GW → Ca SW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.4	35,700	22,420	6,120	403	14	10,400	50.0	47.5	892	<1	10,900	30	142	<4	<5	807	78	<1	1.3	<9	310	10
2	12.6	16,500																					
3	10.6	12,700																					
Comp 2+3			6,002	2,550	86	7.7	1,330	5.6	4.8	786	62	1,370	24	40.3	<4	<5	334	36	3	0.2	<9	92	<6
4	12.4	11,100																					
5	12.7	11,400																					
Comp 4+5			3,350	2,790	47	3.7	820	2.1	1.0	552	8	810	26	7.05	<4	<5	123	26	2	<0.2	<9	37	<6
6	12.5	10,600																					
7	12.4	11,500																					
Comp 6+7			3,042	2,720	47	3.7	477	1.3	0.7	356	<1	772	5	1.71	<4	<5	34	20	3	0.2	<9	15	<6
8	12.5	11,400																					
9	12.5	11,100																					
Comp 8+9			3,000	2,660	48	3.1	457	1.2	0.4	393	<1	794	22	0.91	<4	<5	18	21	3	<0.2	<9	24	<6
10	12.4	10,500	2,772	2,660	43	1.0	320	1.3	0.4	266	1	798	14	0.91	<4	<5	<9	21	2	<0.2	<9	15	<6
INPUT**	8.4	3,770	2,521	754	32	1.1	1,130	1.2	0.1	57	32	773	2	0.89	<4	<5	9	27	6	<0.2	<9	16	860

**Groundwater (28 Dec. 1981)

GW: Groundwater

Ca SW: Calcium based scrubber waste

Comp: Composite sample.

Table 12. Single column experiment data: GW → Na SW.

GW → Na SW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.4	60,800	71,970	13,700	620	124	32,200	24.3	17.0	61	61	23,400	2010	186	<4	7	362	260	<1	1.5	16	2270	14
2	9.9	40,100																					
3	10.1	34,100																					
Comp 2+3			35,740	7,910	337	54	13,000	17.0	11.8	22	30	13,100	870	140	<4	<5	225	118	<1	1.6	<9	1120	<6
4	9.7	30,300																					
5	9.8	29,100																					
Comp 4+5			27,840	6,510	292	63	13,900	4.2	17.4	15	22	12,600	440	113	<4	<5	156	85	<1	0.2	26	1230	<6
6	9.5	21,300																					
7	9.7	18,200																					
Comp 6+7			17,060	4,210	186	34	8,630	0.1	13.4	19	26	9,410	230	60.0	<4	<5	78	47	20	0.4	<9	620	<6
8	9.7	20,100																					
9	9.7	15,500																					
Comp 8+9			14,880	3,430	159	38	6,600	<0.1	11.6	22	24	3,920	280	56.5	<4	<5	62	47	18	1.5	<9	620	<6
10	9.7	14,800	12,080	2,720	112	17	5,920	<0.1	8.1	22	24	3,360	140	42.4	<4	<5	51	34	37	<0.2	<9	240	<6
INPUT**	8.4	3,770	2,521	754	32	1.1	1,130	1.2	<0.1	57	32	773	2	0.89	<4	<5	9	27	6	<0.2	<9	16	860

**Groundwater (28 Dec. 1981)

GW: Groundwater
Na SW: Sodium based scrubber waste
Comp: Composite sample.

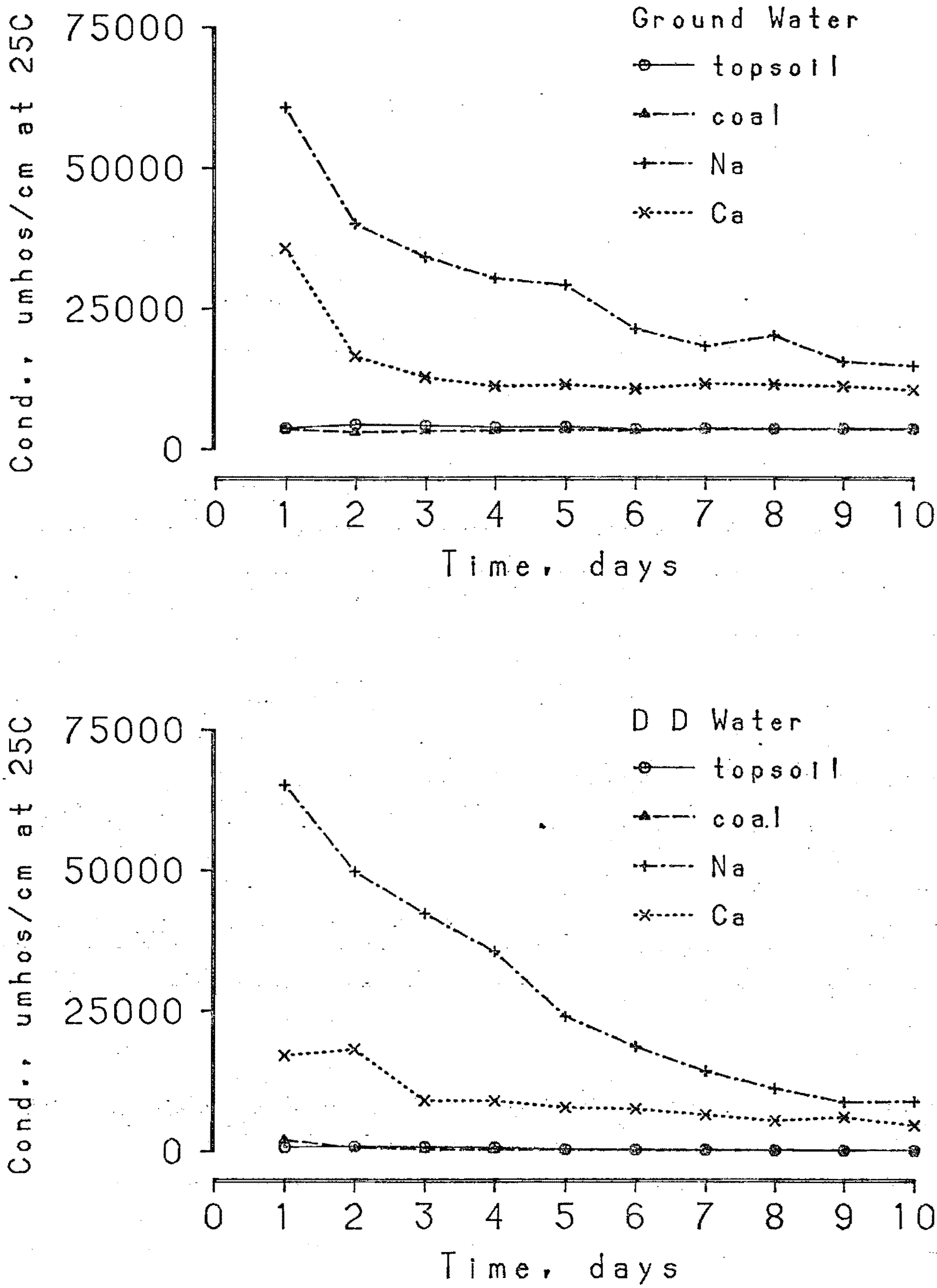


Figure 4. Conductivity results from single-column experiments for topsoil, coal, sodium scrubber waste and calcium scrubber waste using GW and DDW as leaching media.

Table 13. Groundwater and core water data.

Groundwater

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
09/08/81	7.9	3,180	1880	284	29	2.9	470	-	-	31	14	700	11	0.38	<17	14	<15	24	-	1.0	<12	2	210
10/09/81	8.3	2,100	2130	585	30	2.2	890	<0.1	<0.1	38	26	700	<1	0.73	<17	<5	<15	13	<1	<0.1	<12	2	522
11/30/81	8.1	3,430	2478	641	29	1.1	1010	1.1	<0.1	65	23	785	3	0.54	<14	<4	<10	10	<1	0.4	<11	<1	960
12/28/81	8.4	3,770	2521	754	32	1.1	1130	1.2	<0.1	57	32	773	2	0.89	< 4	<5	9	27	6	<0.2	< 9	16	860
Core Water	8.2	10,000	-	1315	187	16	6580	<0.1	0.3	705	51	2200	26	43.5	<17	<5	53	25	7	4.0	<12	<1	181

(see Figures 5-13). Nitrate and nitrite data also followed a similar trend except for the initial data points for the GW → Ca scrubber waste leachate (Figure 14). For chromium (Figure 15) the Ca scrubber wastes initially showed higher levels than the Na scrubber wastes. Arsenic concentrations were high only in the sodium scrubber wastes for both the DDW and the GW with initial concentrations of 1760 and 2010 μg/l respectively. The concentration then decreased with each successive sample date to concentrations of 130 and 140 μg/l respectively on the final composite sample.

All other data did not show any particular trend.

Sequential Leaching Scheme

The data were obtained as described previously following the sequential schemes in Figure 2 using doubly deionized water (DDW) and groundwater (GW). The quality of the GW going through overburden 43 (OB 44) and overburden 44 (OB 44) (GW → OB 43 and GW → OB 44, Tables 14 and 15) was only slightly different than the original quality of the GW (Table 13). Sulfate, nitrate and boron concentrations increase moderately and the zinc concentrations decreased.

The data for DDW through topsoil (TS) are shown in Table 16. The throughput for this experiment is used for the leaching of OB 43 and OB 44. Conductivity, total dissolved solids, total alkalinity, chloride, fluoride, sulfate, nitrate, sodium, calcium, magnesium, boron concentration from DDW → TS → OB 43 and OB 44 (Tables 17 and 18) all show increases over the concentrations of the DDW → TS throughput. As the aqueous DDW → TS solution was passed through the OB 43 and OB 44 materials the highest concentrations of the chemical parameters increasing appeared

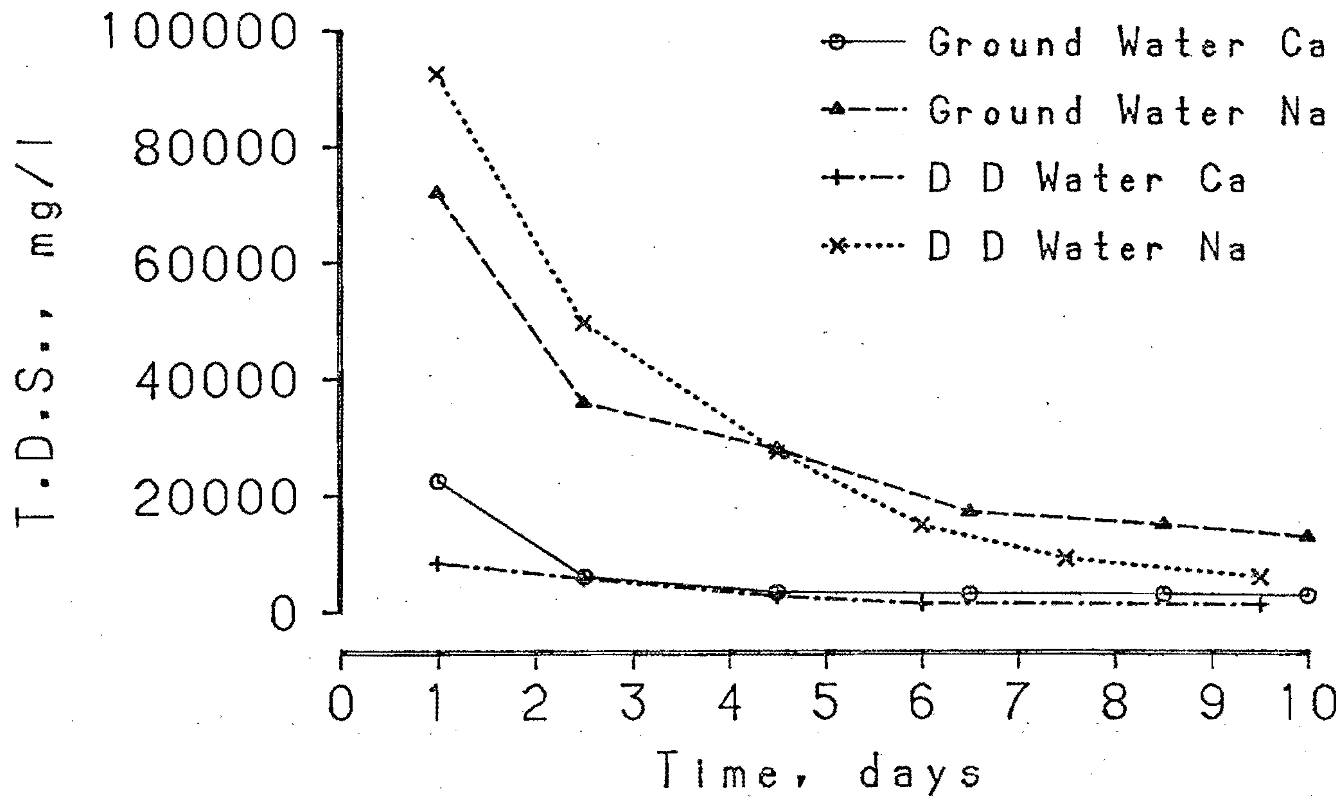


Figure 5. Total dissolved solids results from single column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

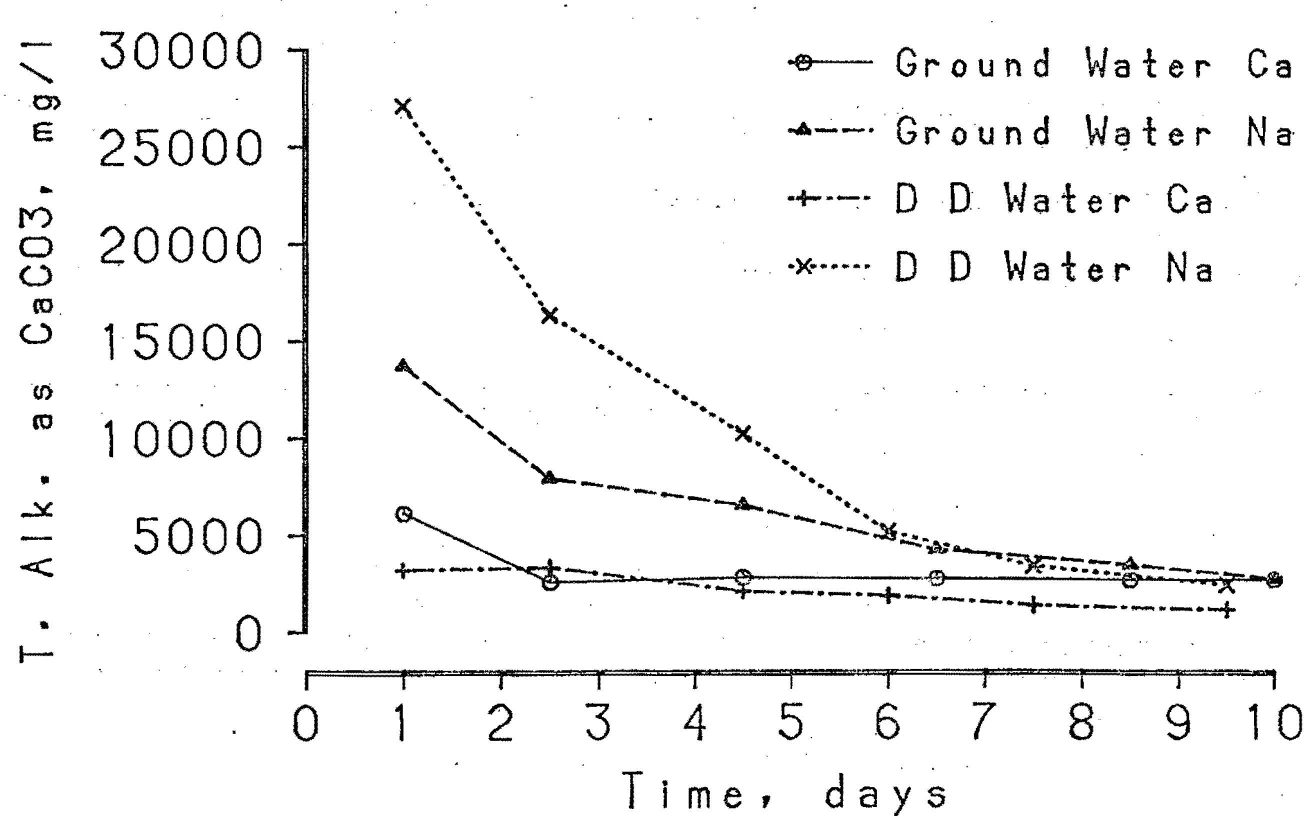


Figure 6. Total alkalinity results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

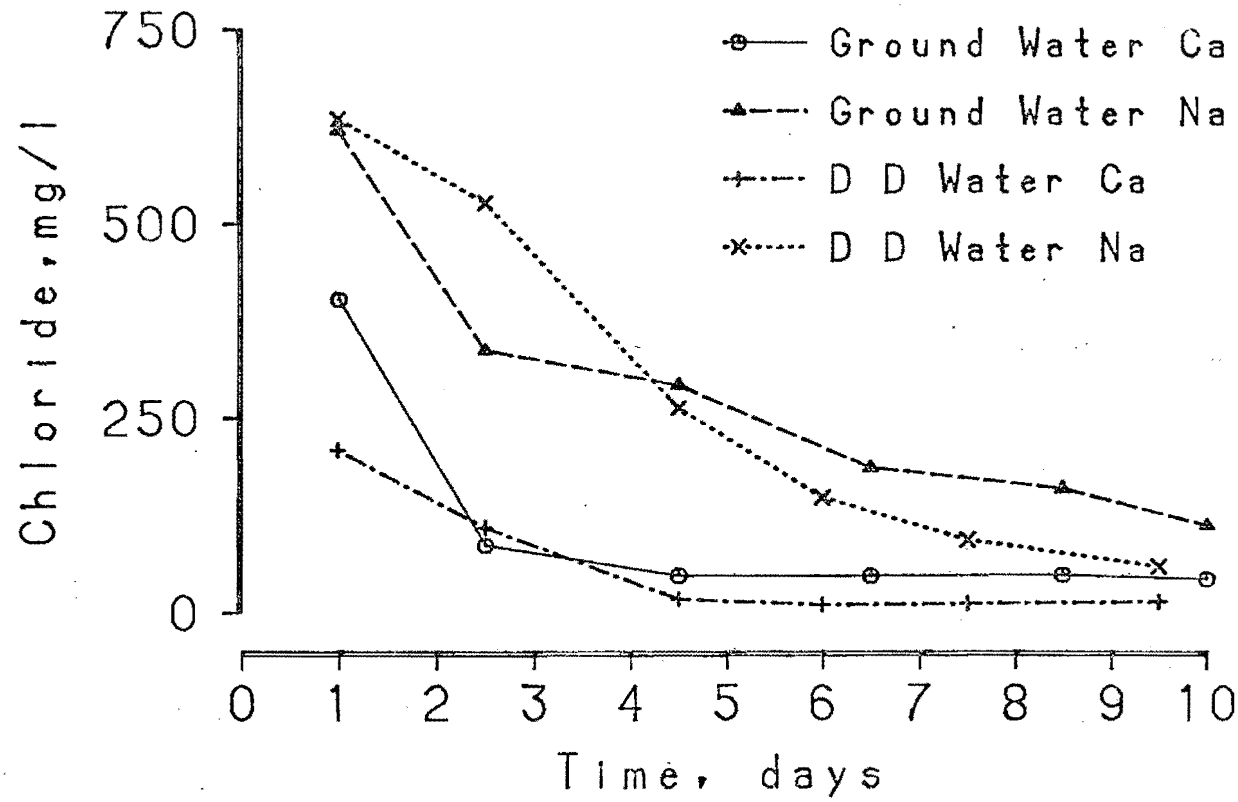


Figure 7. Chloride results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

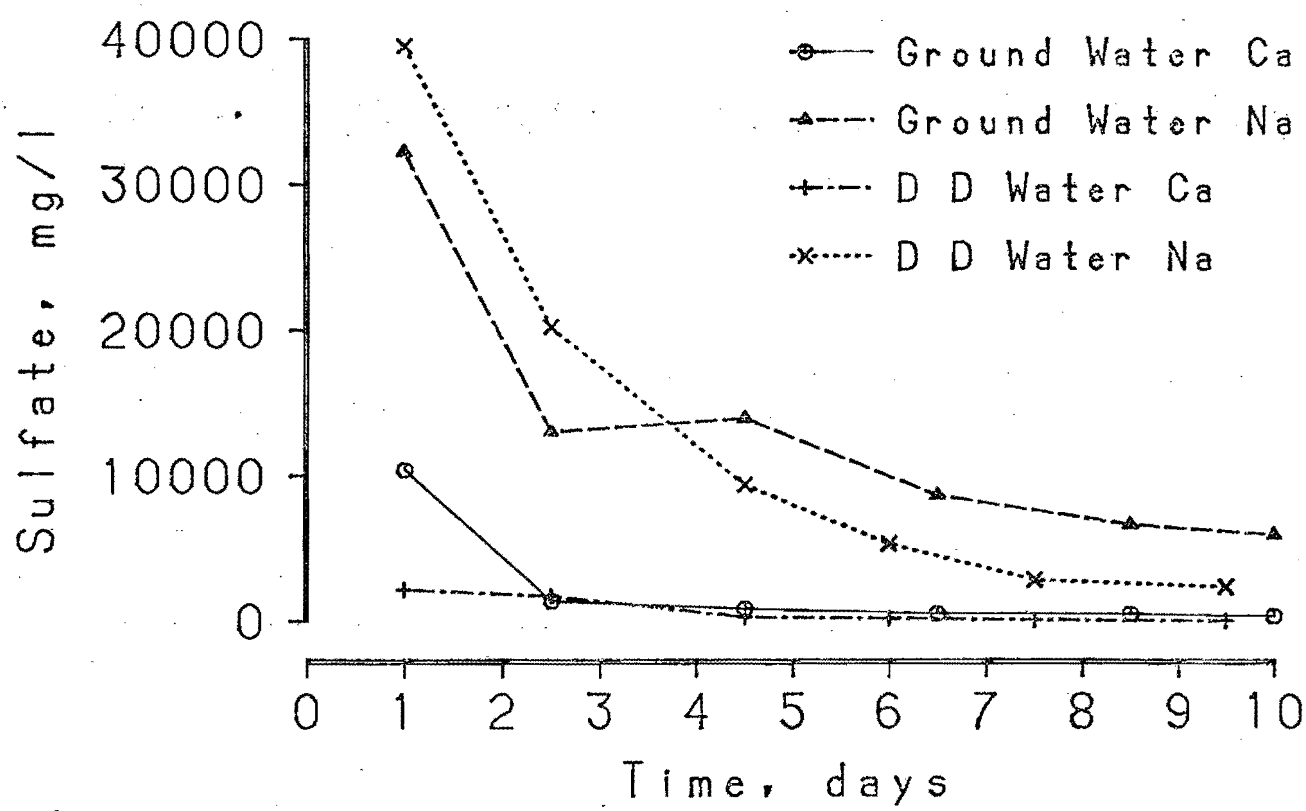


Figure 8. Sulfate results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

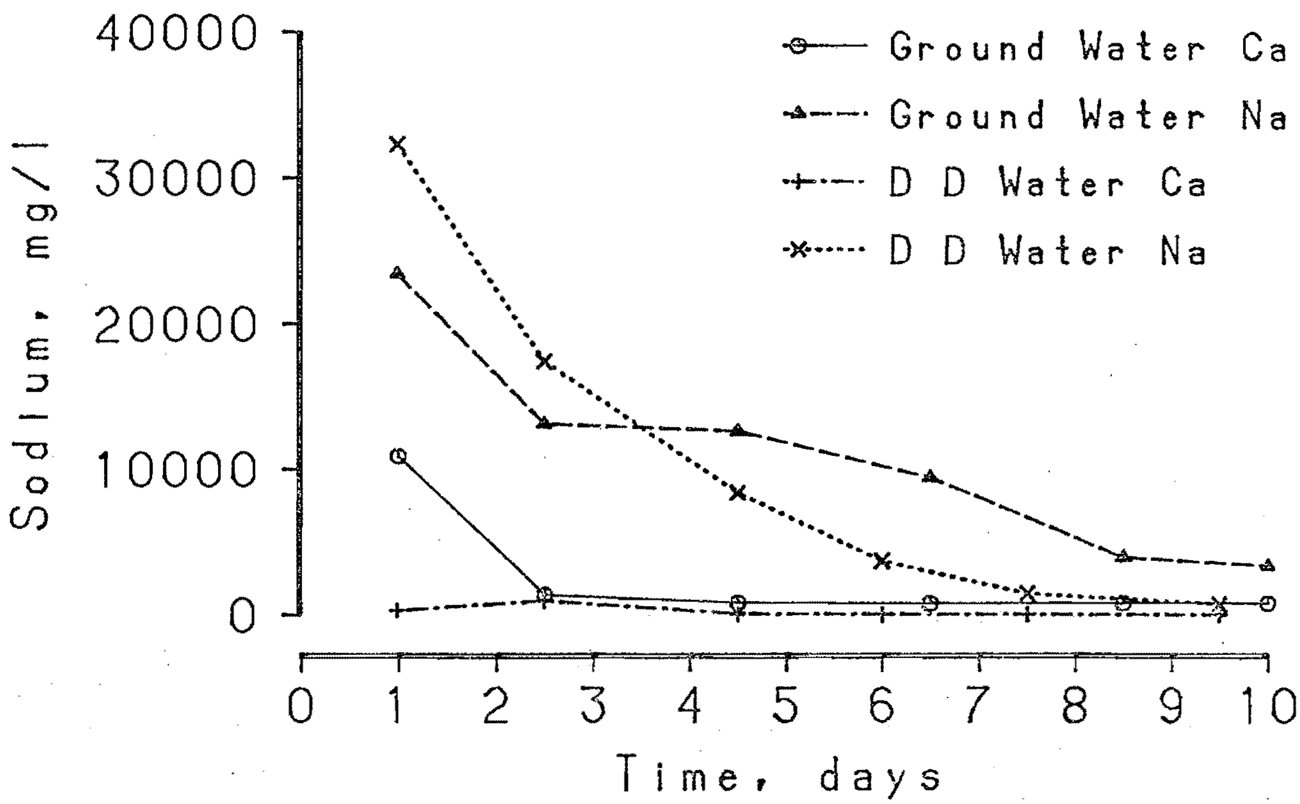


Figure 9. Sodium results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

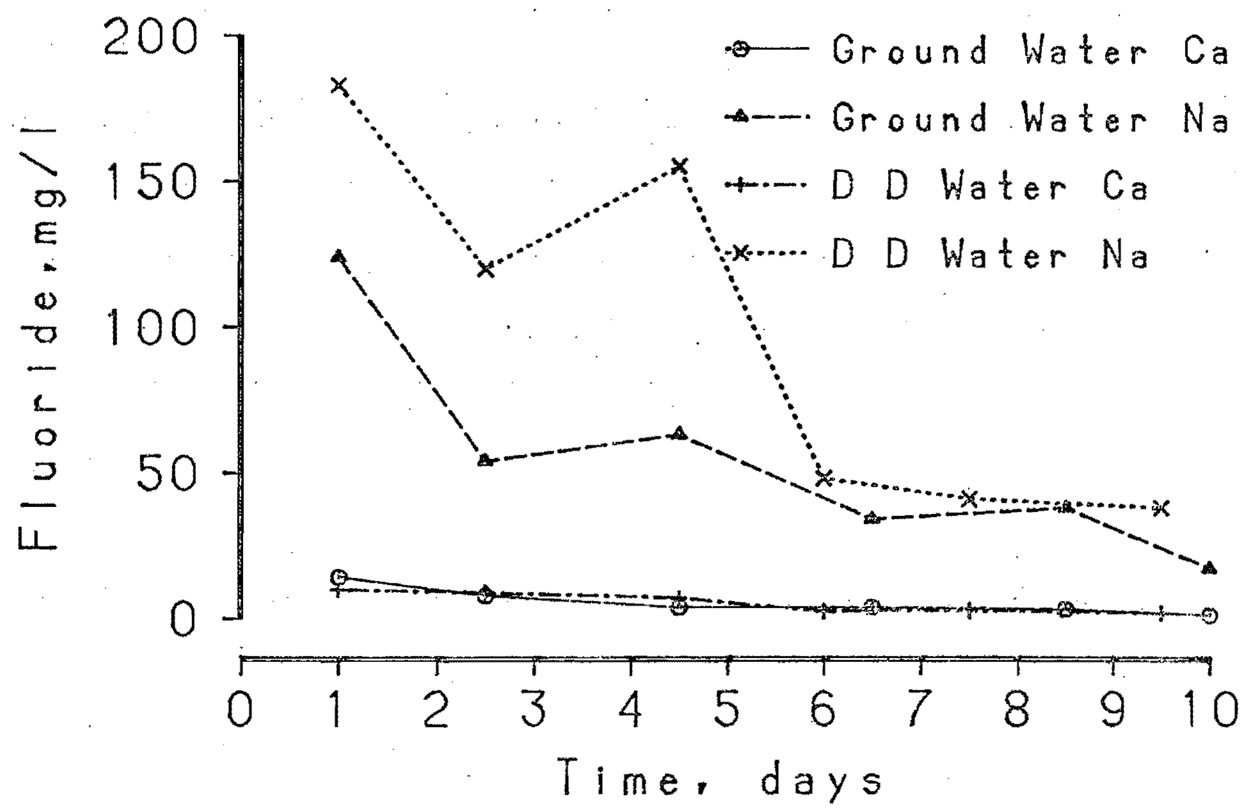


Figure 10. Fluoride results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

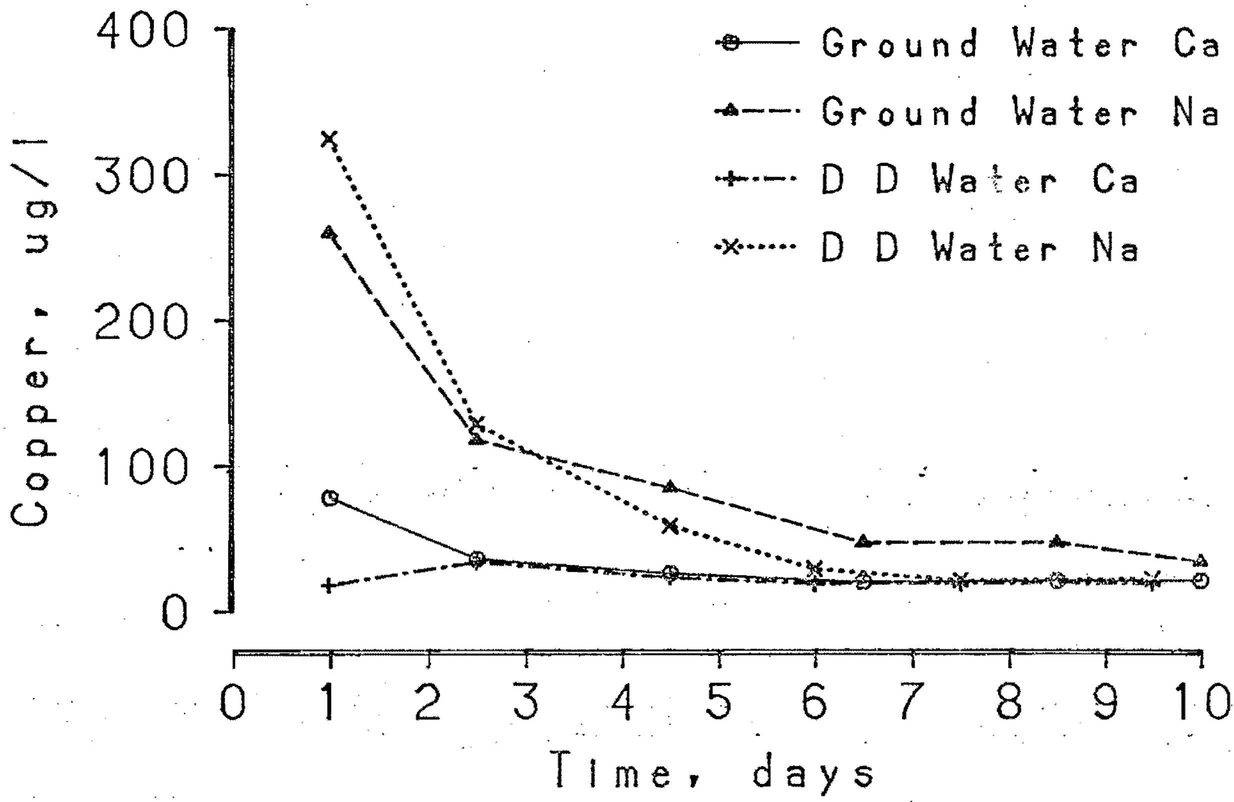


Figure 11. Copper results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

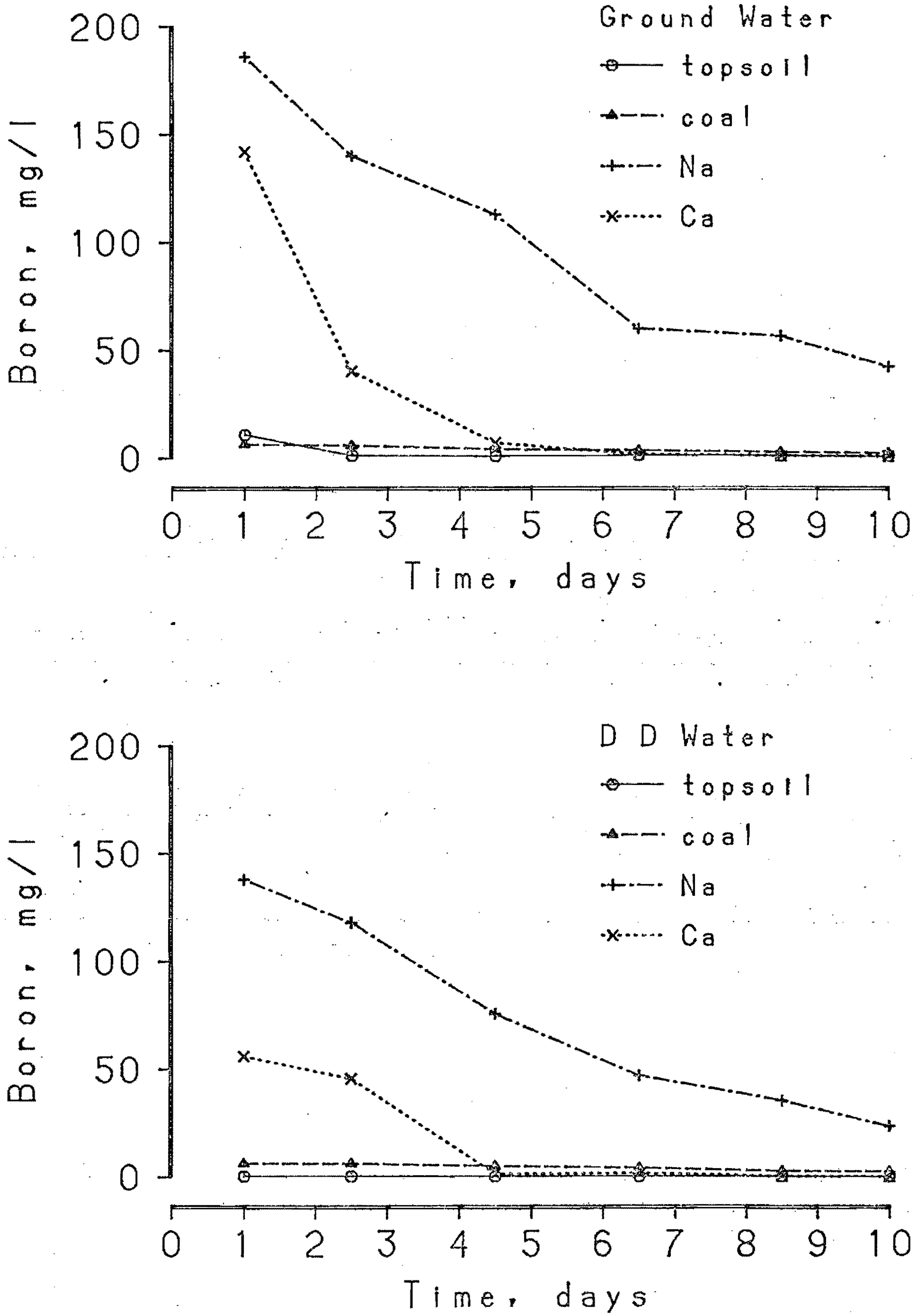


Figure 12. Boron results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

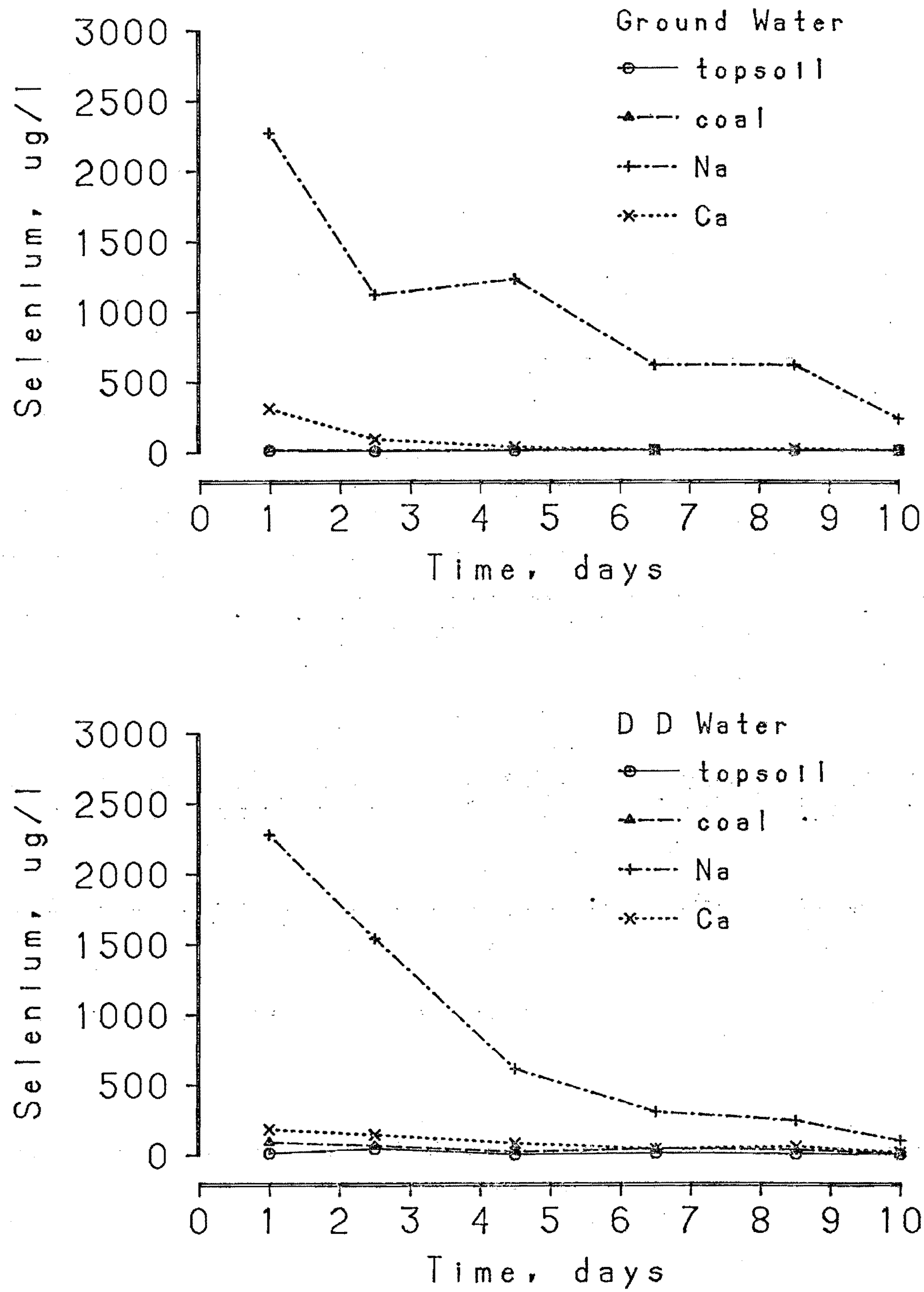


Figure 13. Selenium results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

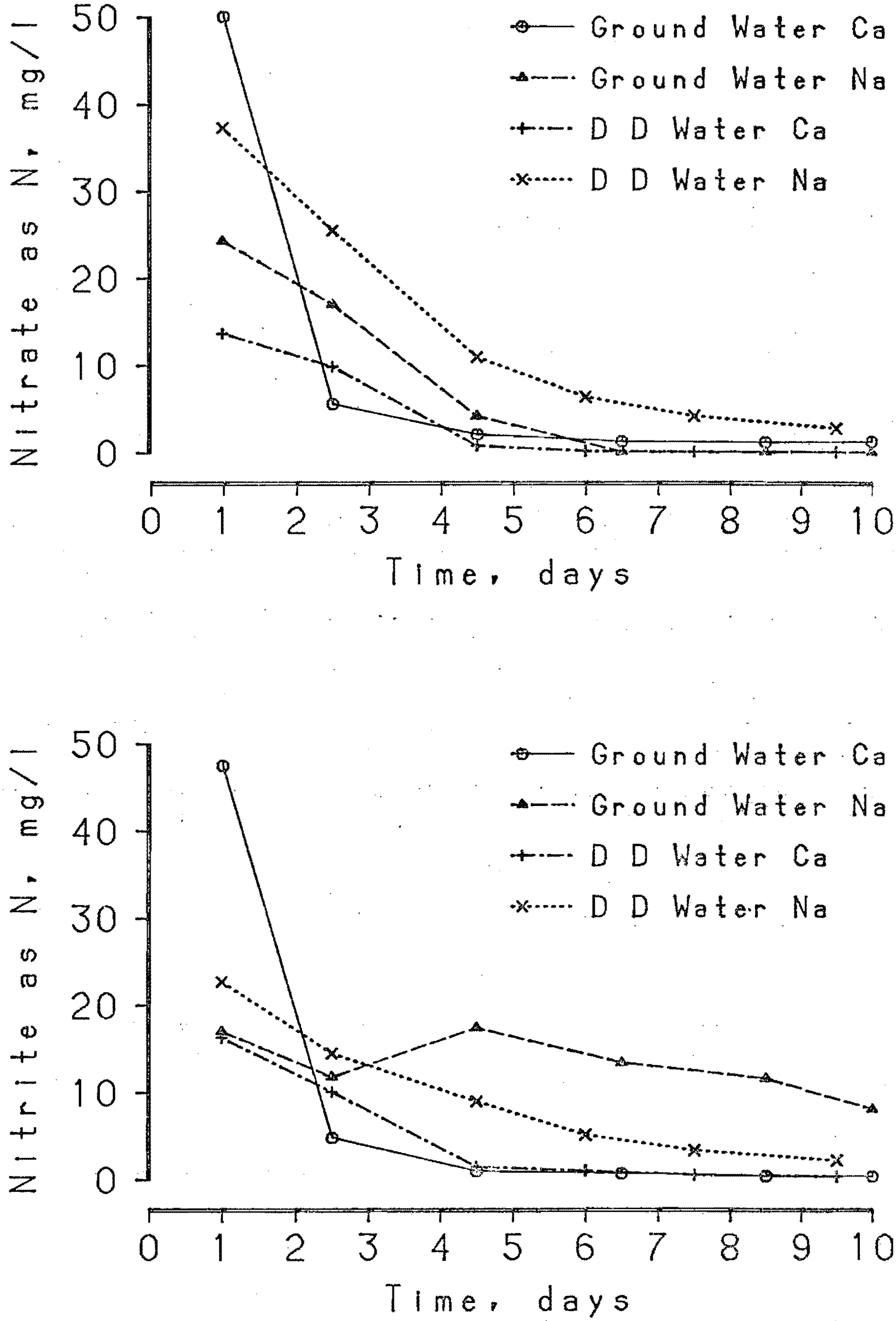


Figure 14. Nitrate and nitrite results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

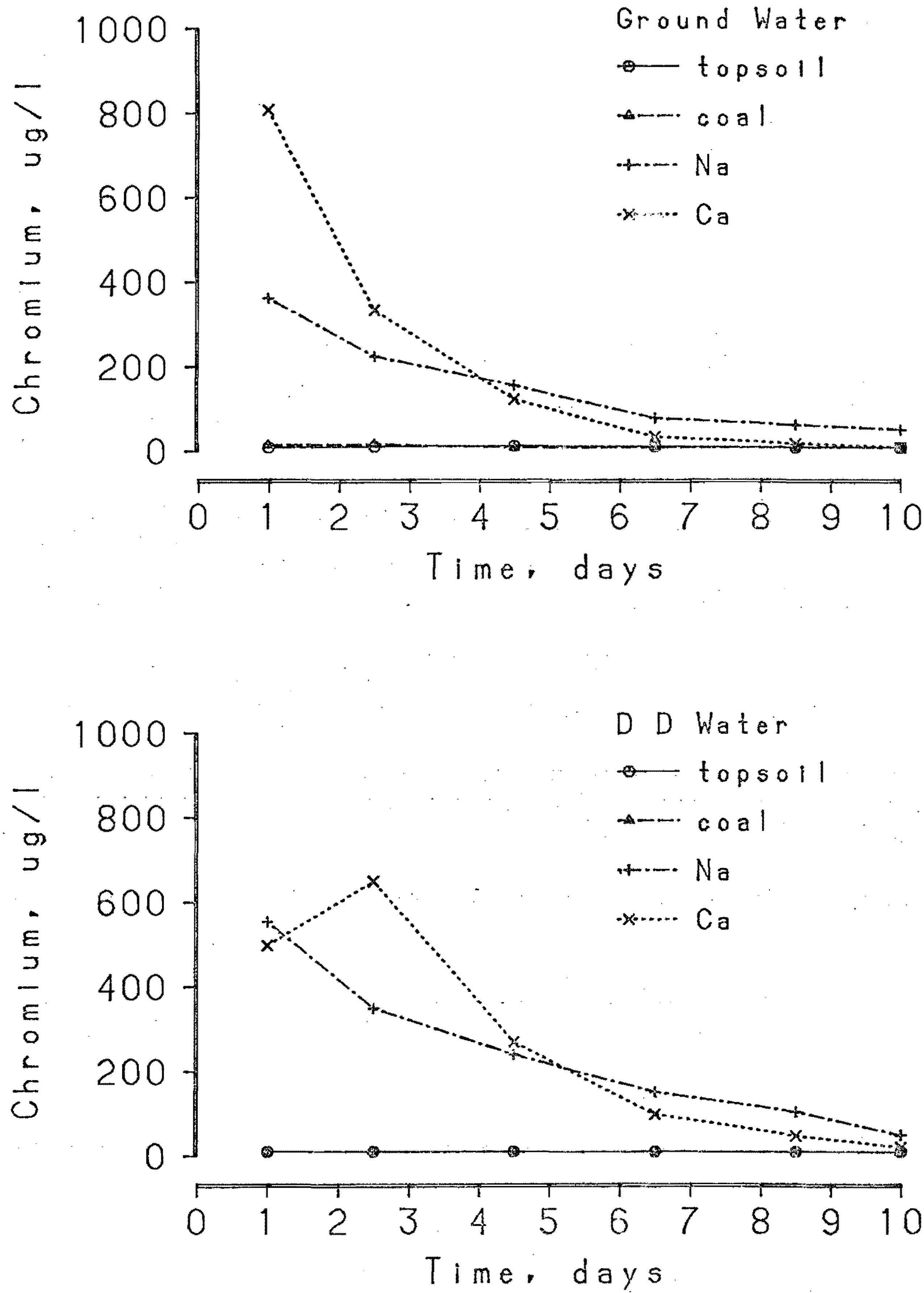


Figure 15. Chromium results from single-column experiments for sodium and calcium scrubber wastes using GW and DDW as leaching media.

Table 14. Sequential column experiment data: GW → OB 43.

GW → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	8.1	2990	2388	607	51	1.7	1200	3.6	0.1	71	50	710	4	1.05	<17	<5	<15	14	<1	0.1	<12	5	40
Comp 2+3	*	*	*	*	*	1.7	1420	5.4	0.1	112	72	700	<1	1.30	<17	<5	<15	17	<1	0.6	<12	8	36
Comp 4+5	8.1	2870	2358	570	40	1.8	1230	2.0	0.2	67	48	670	<1	1.02	<17	<5	<15	13	<1	0.3	<12	4	23
Comp 6+7	8.3	3090	2320	603	38	1.9	989	1.3	0.3	60	35	710	<1	0.93	<17	<5	<15	17	3	0.8	<12	28	12
8	8.0	2790																					
Comp 8+9	8.3	2940	2262	615	35	1.8	1420	2.8	0.3	59	27	710	<1	0.88	<17	<5	<15	19	<1	0.7	<12	4	9
10	8.1	2820																					
Comp 10+11	8.4	3050	2260	649	35	2.1	1030	1.1	0.2	53	32	690	<1	0.76	<17	<5	<15	17	<1	0.8	<12	2	15
12	8.1	3270																					
INPUT**	8.1	2640	2005	435	30	2.6	680	<0.1	<0.1	35	20	700	6	0.56	<17	9	<15	19	<1	0.5	<12	2	370

*Sample contaminated.
**Groundwater (Samples 8 Sept. 1981 and 9 Oct. 1981).

GW: Groundwater
OB: Overburden, core #081043 or #081044
Comp: Composite sample.

Table 15. Sequential column experiment data: GW → OB 44.

GW → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	8.5	3580	2988	624	37	1.9	1800	10.4	<0.1	81	69	830	4	2.21	<17	<5	<15	17	2	0.6	<12	15	15
Comp 2+3	*	*	*	*	*	2.3	2410	28.2	<0.1	141	127	960	<1	4.14	<17	<5	<15	21	<1	0.2	<12	90	14
Comp 4+5	8.4	3700	3044	580	37	2.3	1820	14.6	0.2	87	73	820	<1	2.96	<17	<5	<15	18	<1	0.2	<12	12	18
Comp 6+7	8.5	3460	2642	598	37	2.2	1310	7.2	0.5	69	48	770	4	2.32	<17	<5	<15	16	<1	3.0	<12	6	9
8	8.4	3050																					
Comp 8+9	8.4	3190	2502	589	33	2.2	1350	9.8	0.8	67	48	750	1	2.01	<17	<5	<15	18	2	0.2	<12	22	6
10	8.3	3080																					
Comp 10+11	8.4	3310	2468	652	33	2.2	1230	4.3	0.7	65	39	720	<1	1.67	<17	<5	<15	15	<1	6.0	<12	2	12
12	8.4	3510																					
INPUT**	8.1	2640	2005	435	30	2.6	680	<0.1	<0.1	35	20	700	6	0.56	<17	9	<15	19	<1	0.5	<12	2	370

*Sample contaminated.

**Groundwater (Samples 8 Sept. 1981 and Oct. 1981).

GW: Groundwater
OB: Overburden, core #081043 or #081044
Comp: Composite sample.

Table 16. Sequential column experiment data: DDW → topsoil.

DDW → Topsoil

	pH	EC µmhos/cm at 25°C	TDS mg/1	Total Alkalinity as $CaCO_3$ mg/1	Chloride mg/1	Fluoride mg/1	Sulfate mg/1	Nitrate as N, mg/1	Nitrite as N, mg/1	Calcium mg/1	Magnesium mg/1	Sodium mg/1	Arsenic µg/1	Boron mg/1	Beryllium µg/1	Cadmium µg/1	Chromium µg/1	Copper µg/1	Lead µg/1	Mercury µg/1	Nickel µg/1	Selenium µg/1	Zinc µg/1
Day 1	8.2	682	968	29	25	0.7	244	1.3	0.1	69	22	47	15	0.20	<14	<4	<10	13	<1	1.0	<11	13	13
2	8.0	810																					
3	8.0	730																					
Comp 2+3			512	32	14	1.0	271	1.5	0.1	73	17	52	18	0.19	<14	<4	<10	15	<1	6.0	<11	44	24
4	8.1	632																					
5	8.4	307																					
Comp 4+5			316	44	13	1.1	141	0.8	0.1	44	11	30	15	0.19	<14	<4	<10	13	<1	8.0	<11	3	11
6	8.5	268																					
7	8.5	231																					
Comp 6+7			158	44	4	0.8	62	0.2	<0.1	28	5	<18	16	0.18	<14	<4	<10	9	<1	0.2	<11	13	19
8	8.4	145																					
9	8.4	113																					
Comp 8+9			96	41	2	0.7	24	0.1	<0.1	16	5	<18	15	<0.10	<14	<4	<10	<7	<1	0.5	<11	8	22
10	8.4	113																					
11	8.4	122																					
Comp 10+11			84	46	1	0.6	22	<0.1	<0.1	16	8	4	17	0.12	<14	<4	<10	<7	<1	<0.2	<11	5	18

DDW: Doubly deionized water
Comp: Composite sample.

Table 17. Sequential column experiment data: DDW → TS → OB 43.

DDW → topsoil → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	7.9	934	634	58	21	0.8	268	3.7	0.1	67	35	61	15	0.44	<14	<4	<10	<7	<1	0.2	<11	7	7
2	7.8	1,130																					
3	8.1	1,100																					
Comp 2+3			1,080	30	42	0.8	730	5.4	0.2	117	76	81	14	0.93	<14	<4	<10	<7	<1	0.3	<11	14	23
4	8.1	1,150																					
5	8.0	981																					
Comp 4+5			772	155	31	0.8	313	3.3	0.2	93	52	68	2	0.65	<4	<5	<9	20	<1	<0.2	<9	22	15
6	8.1	921																					
7																							
Comp 6+7			592	134	23	0.8	237	1.6	0.2	77	38	34	6	0.50	<14	<4	<10	<7	<1	0.4	<11	17	17
8	8.1	770																					
9	8.1	687																					
Comp 8+9			504	116	24	0.8	206	0.9	0.2	63	30	29	6	0.58	<14	<4	<10	10	<1	0.2	<11	9	34
10	8.1	611																					
11	8.1	685																					
Comp 10+11			432	108	17	0.8	188	0.5	0.2	57	44	25	7	0.54	<14	<4	<10	37	<1	0.4	<11	15	10
INPUT**	8.3	377	300	40	8	0.8	117	0.6	0.1	38	10	26	16	0.16	<14	<4	<10	11	<1	2.8	<11	14	18

**"Weighted Mean" of DDW → TS

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Comp: Composite sample.

Table 18. Sequential column experiment data: DDW → TS → OB 44.

DDW → topsoil → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	8.1	1,270	904	43	38	1.3	522	9.4	<0.1	93	38	94	17	1.35	<14	<4	<10	11	<1	<0.2	<11	8	11
2	7.9	2,710																					
3	8.0	2,460																					
Comp 2+3			2,714	42	28	1.8	1,530	40.6	0.4	190	140	300	14	4.16	<14	<4	<10	15	<1	2.0	<11	28	25
4	8.1	2,330																					
5	8.0																						
Comp 4+5			1,726	72	17	1.7	1,090	22.9	0.5	137	82	223	2	3.10	<4	<5	<9	23	4	<0.2	<9	13	11
6	8.1	1,410																					
7																							
Comp 6+7			886	65	13	1.5	514	9.67	0.3	87	41	99	5	1.77	<14	<4	<10	<7	<1	<0.2	<11	13	13
8	8.0	1,100																					
9	8.1	909																					
Comp 8+9			684	63	11	1.6	392	7.4	0.3	76	35	67	4	1.62	<14	<4	<10	<6	<1	<0.2	<11	12	11
10	8.0	758																					
11	8.1	732																					
Comp 10+11			504	64	11	1.2	262	5.4	0.2	66	26	41	7	1.21	<14	<4	<10	8	<1	<0.2	<11	9	11
INPUT**	8.3	377	300	40	8	0.8	117	0.6	0.1	38	10	26	16	0.16	<14	<4	<10	11	<1	2.8	<11	14	18

**"Weighted Mean" of DDW → TS

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Comp: Composite sample.

to be at the composite sample of days 2 and 3. This was also observed for the leachate when GW was used as the leaching media for OB 43 and OB 44. Most all of the major cations and anion chemical parameters measured were higher in the GW leachate than the DDW leachate of the overburden materials due to the poorer quality of the GW.

Some of the most interesting and intriguing data were obtained when leaching the sodium scrubber wastes (Na SW) and calcium scrubber wastes (Ca SW) with the aqueous leachate from DDW → TS → OB 43, DDW TS → OB 44, GW → OB 43 and GW → OB 44 (Tables 19-26). The Na SW produced a leachate with a pH of approximately 10.4 for both the GW and DDW based leachates. The Ca SW pH was in the range of 12.4 - 12.6 for both the DDW and GW based leachates. All of the pH values were higher than the initial aqueous leaching media shown as input on the data tables. The conductivity of the Na SW and Ca SW leachates was very high. The Na SW produced the highest conductivity reading for both the DDW and GW based leaching solutions (Figure 16). Total dissolved solids, total alkalinity, chloride, fluoride, sulfate, sodium, arsenic, boron, copper, and selenium followed trends similar to the conductivity (Figures 17-25). As can be observed from the figures mentioned above the DDW → TS → OB 43 leachate seemed to leach slightly more material from the Na SW than the DDW → TS → OB 44. For the groundwater, the GW → OB 44 leachate appeared to leach more material from the Na SW than the GW → OB 43 leachate. In general for the major cations and anions, the Na SW released higher concentrations than the Ca SW. This is probably due to the general phenomenon that monovalent cation salts of this nature are more soluble than the similar divalent cation salts (sodium vs calcium). There is also the possibility that the Na scrubbing process may be more efficient than the

Table 19. Sequential column experiment data: DDW → TS → OB 43 → Ca SW.

DDW → topsoil → OB 081043 → CaSW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.7	17,400	8,285	3,020	148	5.5	2,390	32.4	12.0	893	<1	437	15	21.9	<14	<4	741	26	1	0.4	<11	71	8
2	12.4	20,100																					
3	12.2	12,600																					
Comp 2+3			7,502	3,050	125	6.5	2,440	21.0	11.5	864	8	404	11	27.7	<14	<4	769	20	<1	1.2	<11	51	7
4	12.2	10,500																					
5	12.8	8,490																					
Comp 4+5			3,241	2,500	52	5.3	543	9.7	2.5	836	8	407	16	8.26	<14	<4	273	29	3	0.5	<11	41	15
6	12.1	8,100																					
7	12.3	8,000																					
Comp 6+7			2,053	2,890	30	4.4	150	2.4	0.9	764	<1	95	14	1.74	<14	<4	64	25	<1	<0.2	<11	43	12
8	12.2	8,280																					
9	12.1	5,540																					
Comp 8+9			1,672	1,610	24	4.3	106	2.9	0.9	563	<1	88	12	1.35	<14	<4	25	21	<1	0.4	<11	32	23
INPUT**	8.0	897	672	104	27	0.8	329	2.5	0.2	80	47	49	8	0.62	<14	<4	<10	15	<1	0.3	<11	15	19

**"Weighted Mean" of DDW → TS → OB 43

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 20. Sequential column experiment data: DDW → TS → OB 44 → Ca SW.

DDW → topsoil → OB 081044 → Ca SW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.8	20,000	9,967	3,330	228	8.1	4,480	62.5	2.0	824	<1	1,020	21	59.6	<14	<4	1,520	16	<1	0.7	<11	112	13
2	12.4	18,700																					
3	12.2	13,400																					
Comp 2+3			7,319	3,070	153	9.5	2,620	29.7	12.8	917	6	433	23	35.4	15	<4	1,120	16	1	0.9	<11	51	14
4	12.2	10,800																					
5	12.8	9,600																					
Comp 4+5			2,997	2,890	31	6.6	436	9.8	2.2	816	33	330	15	7.06	16	<4	203	28	<1	0.4	<11	71	10
6	12.3	7,880																					
7	12.3	8,200																					
Comp 6+7			2,225	2,680	19	6.5	126	12.0	1.7	605	4	255	21	1.86	<14	<4	125	18	<1	0.2	<11	48	10
8	12.3	8,400																					
9	12.3	8,430																					
Comp 8+9			2,066	1,970	16	6.0	47	12.0	1.3	601	9	213	19	1.16	<14	<4	45	24	<1	<0.2	<11	51	8
INPUT**	8.0	1,370	1,266	59	18	1.5	736	16.5	0.3	109	62	141	7	2.28	<14	<4	<10	11	<1	<0.2	11	14	14

**"Weighted Mean" of DDW → TS → OB 44

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 21. Sequential column experiment data: DDW → TS → OB 43 → Na SW.

DDW → topsoil → OB 081043 → Na SW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.7	75,300	122,900	34,200	946	144	51,400	93.5	31.5	87	164	43,400	1890	224	15	<4	777	450	<1	15.1	<11	3680	34
2	9.5	71,900																					
3	9.9	56,700																					
Comp 2+3			87,380	24,800	867	140	35,600	53.5	29.0	36	53	30,600	2160	243	<14	<4	666	305	<1	3.2	15	2190	9
4	10.2	40,900																					
5	11.1	29,800																					
Comp 4+5			33,900	14,200	348	186	8,540	17.2	11.0	22	9	10,800	740	123	15	<4	326	78	<1	0.7	<11	1040	12
6	10.9	15,100																					
7	10.7	9,730																					
Comp 6+7			9,451	4,870	111	114	865	7.0	3.3	15	4	1,630	320	42.9	<14	<4	131	27	<1	0,5	<11	276	12
8	10.8	4,690																					
9	10.9	3,570																					
Comp 8+9			2,646	1,170	50	84	917	3.4	1.2	26	2	934	240	19.5	<14	<4	49	14	<1	0.6	<11	510	<5
INPUT**	8.0	897	672	104	27	0.8	329	2.5	0.2	80	47	49	8	0.62	<14	<4	<10	15	<1	0.3	<11	15	19

**"Weighted Mean" of DDW → TS → OB 43

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 22. Sequential column experiment data: DDW → TS → OB 44 → Na SW.

DDW → topsoil → OB 081044 → Na SW

	pH	EC µmhos/cm at 25°C	TDS mg/1	Total Alkalinity as $CaCO_3$ mg/1	Chloride mg/1	Fluoride mg/1	Sulfate mg/1	Nitrate as N, mg/1	Nitrite as N, mg/1	Calcium mg/1	Magnesium mg/1	Sodium mg/1	Arsenic µg/1	Boron mg/1	Beryllium µg/1	Cadmium µg/1	Chromium µg/1	Copper µg/1	Lead µg/1	Mercury µg/1	Nickel µg/1	Selenium µg/1	Zinc µg/1
Day 1	9.7	80,100	118,500	37,000	1,020	144	45,900	59.5	66.5	92	160	42,100	1590	201	<14	<4	582	423	<1	1.7	<11	3160	242
2	9.6	62,800																					
3	9.9	52,700																					
Comp 2+3			71,100	22,900	629	154	28,000	56.0	21.5	32	36	24,200	1520	172	<14	8	460	198	<1	1.7	<11	1970	<5
4	10.3	37,000																					
5	11.0	25,800																					
Comp 4+5			28,730	11,300	288	112	6,010	33.2	9.3	24	9	8,680	393	83.3	<14	<4	223	79	<1	4.3	<11	610	19
6	10.6	19,600																					
7	10.8	9,550																					
Comp 6+7			12,270	5,330	116	79	5,830	21.0	6.5	25	11	2,960	290	44.7	<14	<4	135	41	<1	0.3	<11	550	17
8	10.7	11,800																					
9	10.7	11,300																					
Comp 8+9			8,539	2,380	87	68	3,780	15.0	5.6	41	8	1,230	220	33.7	<14	<4	83	24	<1	0.7	<11	255	<5
INPUT**	8.0	1,370	1,266	59	18	1.5	736	16.5	0.3	109	62	141	7	2.28	<14	<4	<10	11	<1	<0.2	<11	14	14

**"Weighted Mean" of DDW → TS → OB 44

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 23. Sequential column experiment data: GW → OB 43 → Ca SW.

GW → OB 081043 → Ca SW

	pH	EC µmhos/cm at 25°C	TDS mg/1	Total Alkalinity as $CaCO_3$ mg/1	Chloride mg/1	Fluoride mg/1	Sulfate mg/1	Nitrate as N, mg/1	Nitrite as N, mg/1	Calcium mg/1	Magnesium mg/1	Sodium mg/1	Arsenic µg/1	Boron mg/1	Beryllium µg/1	Cadmium µg/1	Chromium µg/1	Copper µg/1	Lead µg/1	Mercury µg/1	Nickel µg/1	Selenium µg/1	Zinc µg/1
Day 1	12.8	23,900	13,360	4,065	229	9.7	5,490	43.6	0.2	886	18	4,300	6	62.2	<14	<4	795	32	<1	2.0	17	113	12
2	12.6	20,700																					
3	12.5	10,700																					
Comp 2+3			6,984	3,120	212	6.0	2,160	13.4	<0.1	904	64	612	6	40.0	<14	<4	763	31	<1	0.8	<11	151	17
4	12.6	12,050																					
5	12.6	12,800																					
Comp 4+5			4,419	2,393	70	4.9	1,220	3.3	1.9	777	85	781	2	13.6	<14	<4	376	30	10	2.0	<11	131	12
6	12.6	11,500																					
7	12.6	10,600																					
Comp 6+7			3,138	2,250	62	4.4	632	2.3	1.2	557	31	763	4	5.65	<14	<4	147	23	7	2.0	<11	101	27
8	12.6	9,680																					
Comp 8+9			2,706	2,270	57	4.0	197	2.4	1.8	380	87	768	6	0.99	<14	<4	30	19	1	10.0	<11	100	*
9	12.7	10,000																					
10	12.8	10,300	2,269	2,040	50	3.0	182	1.5	1.9	208	11	759	7	1.92	14	<4	14	16	<1	0.7	<11	100	<5
INPUT**	8.2	2,980	2,318	609	39	1.8	1,220	2.6	0.2	70	43	697	<1	0.98	<17	<5	<15	16	<1	0.6	<12	9	21

*Sample contaminated.
**"Weighted Mean" of GW → OB 43

GW: Groundwater
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 24. Sequential column experiment data: GW → OB 44 → Ca SW.

GW → OB 081044 → Ca SW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.8	26,700	16,270	4,265	231	13.8	7,730	44.4	7.1	956	8	5,000	5	50.2	<14	<4	496	34	<1	2.0	<11	232	20
2	12.7	22,100																					
3	12.6	17,500																					
Comp 2+3			8,466	3,355	150	7.6	2,970	25.0	3.5	847	36	2,410	4	33.0	<14	<4	655	36	<1	5.0	<11	241	17
4	12.6	13,600																					
5	12.5	12,200																					
Comp 4+5			4,917	2,460	64	5.4	1,530	12.9	2.6	799	40	1,210	5	12.1	<14	<4	326	28	6	6.0	<11	121	7
6	12.5	11,700																					
7	12.5	11,400																					
Comp 6+7			4,350	3,880	58	5.4	1,560	12.5	1.5	790	23	863	5	8.30	<14	<4	121	31	<1	0.5	<11	181	21
8	12.6	10,800	3,564	2,115	45	4.2	621	8.6	2.1	390	11	871	4	2.85	<14	<4	52	22	<1	2.0	<11	141	*
INPUT**	8.4	3,360	2,700	607	35	2.2	1,640	12.6	0.4	85	67	806	<1	2.6	<17	<5	<15	17	<1	1.8	<12	25	12

*Insufficient sample.
**"Weighted Mean" of GW → OB 44

GW: Groundwater
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 25. Sequential column experiment data: GW → OB 43 → Na SW.

GW → OB 081043 → Na SW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.8	70,800	80,730	15,450	614	121	34,900	33.4	2.3	65	47	28,500	1530	148	<14	9	510	166	<1	3.0	71	2140	40
2	9.7	55,800																					
3	10.1	44,200																					
Comp 2+3			53,440	11,500	569	87	13,600	28.0	<0.1	43	43	18,500	1430	119	<14	<4	417	115	<1	0.3	<11	1530	15
4	10.3	35,100																					
5	10.2	28,300																					
Comp 4+5			9,651	6,040	303	81	13,000	16.8	0.6	23	25	10,900	1010	79.2	<14	4	321	54	<1	5.0	<11	1210	9
6	10.2	21,500																					
7	10.1	16,100																					
Comp 6+7			15,920	3,320	172	60	7,000	5.8	6.2	21	25	5,760	540	52.8	<14	<4	121	35	14	1.0	<11	780	5
8	10.2	13,800																					
Comp 8+9			10,800	2,410	132	26	5,300	2.9	5.5	15	22	4,020	350	39.4	<14	<4	118	25	<1	1.0	<11	560	*
9	10.1	12,900																					
10	10.0	10,200	6,533	1,100	87	37	3,180	2.0	2.8	17	19	2,420	267	27.0	<14	<4	43	19	<1	8.0	<11	330	8
INPUT**	8.2	2,980	2,318	609	39	1.8	1,220	2.6	0.2	70	43	697	<1	0.98	<17	<5	<15	16	<1	0.6	<12	9	21

**"Weighted Mean" of GW → OB 43

GW: Groundwater
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

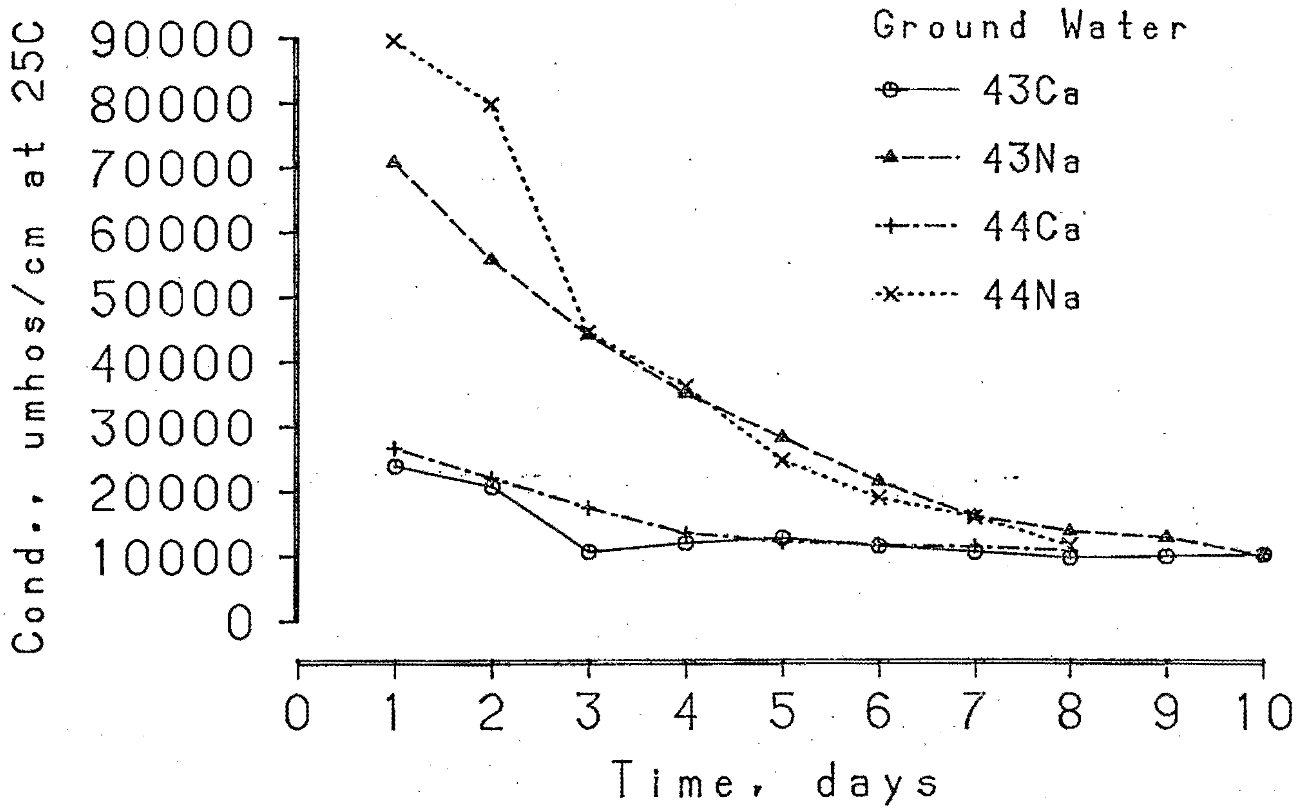
Table 26. Sequential column experiment data: GW → OB 44 → Na SW.

GW → OB 081044 → Na SW

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.7	89,600	119,500	33,200	1,130	183	51,800	59.4	17.6	142	30	43,300	1750	157	<14	7	631	274	<1	0.4	52	2270	56
2	9.7	79,800																					
3	10.2	44,600																					
Comp 2+3			78,960	21,700	769	147	32,500	46.8	11.2	40	30	28,300	1650	153	<14	5	631	139	<1	0.7	<11	1860	25
4	10.7	36,200																					
5	11.1	24,800																					
Comp 4+5			28,320	8,665	261	99	11,200	21.4	0.4	23	11	10,600	760	92.9	<14	4	289	53	<1	4.0	<11	1010	7
6	11.7	19,000																					
7	11.3	16,000																					
Comp 6+7			14,420	2,200	142	69	5,140	13.3	5.0	14	2	5,430	380	56.9	<14	<4	185	29	<1	3.2	<11	463	7
8	11.3	11,600	9,252	3,060	107	51	3,930	9.6	5.4	11	3	3,820	280	38.2	<14	<4	110	21	<1	7.6	<11	341	6
INPUT**	8.4	3,360	2,700	607	35	2.2	1,640	12.6	0.4	85	67	806	<1	2.6	<17	<5	<15	17	<1	1.8	<12	25	12

**"Weighted Mean" of GW → OB 44

CW: Croundwater
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.



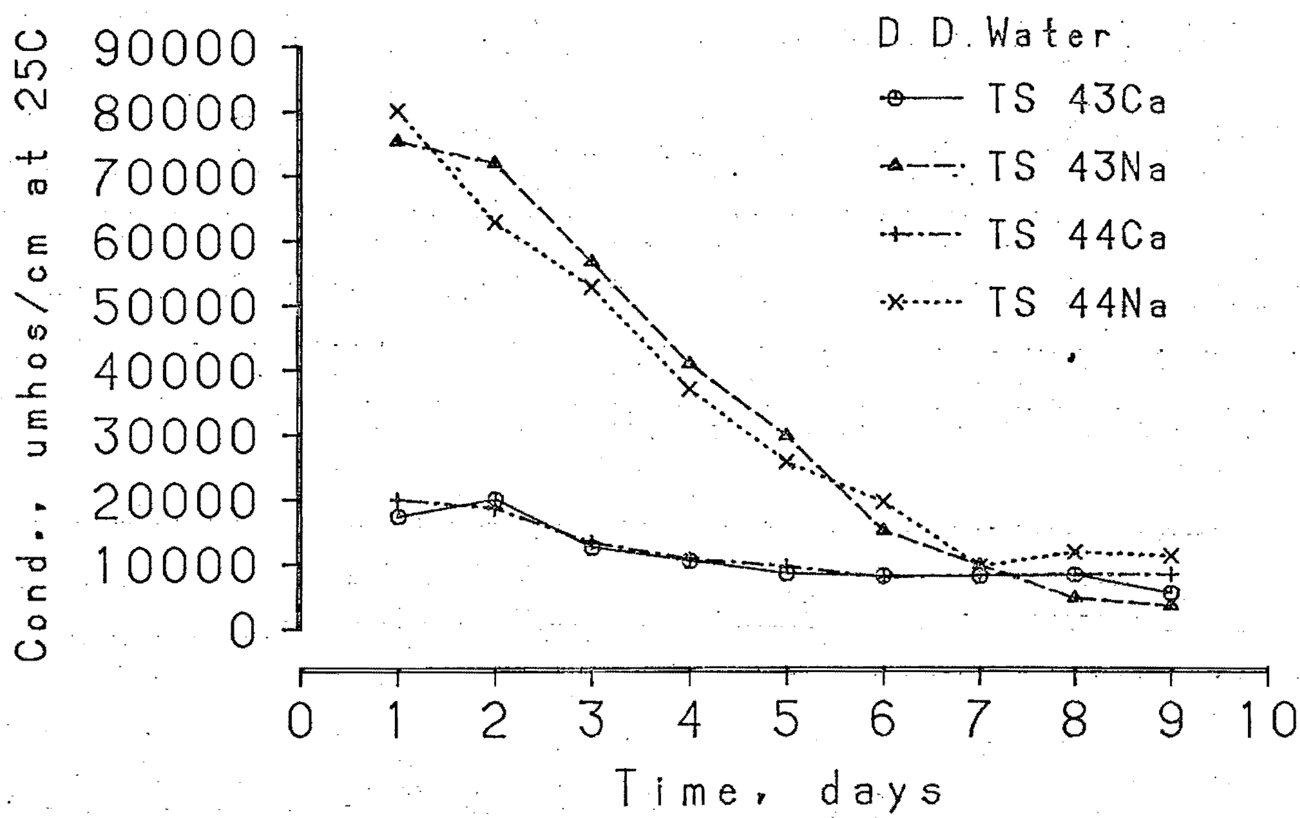


Figure 16. Conductivity results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.

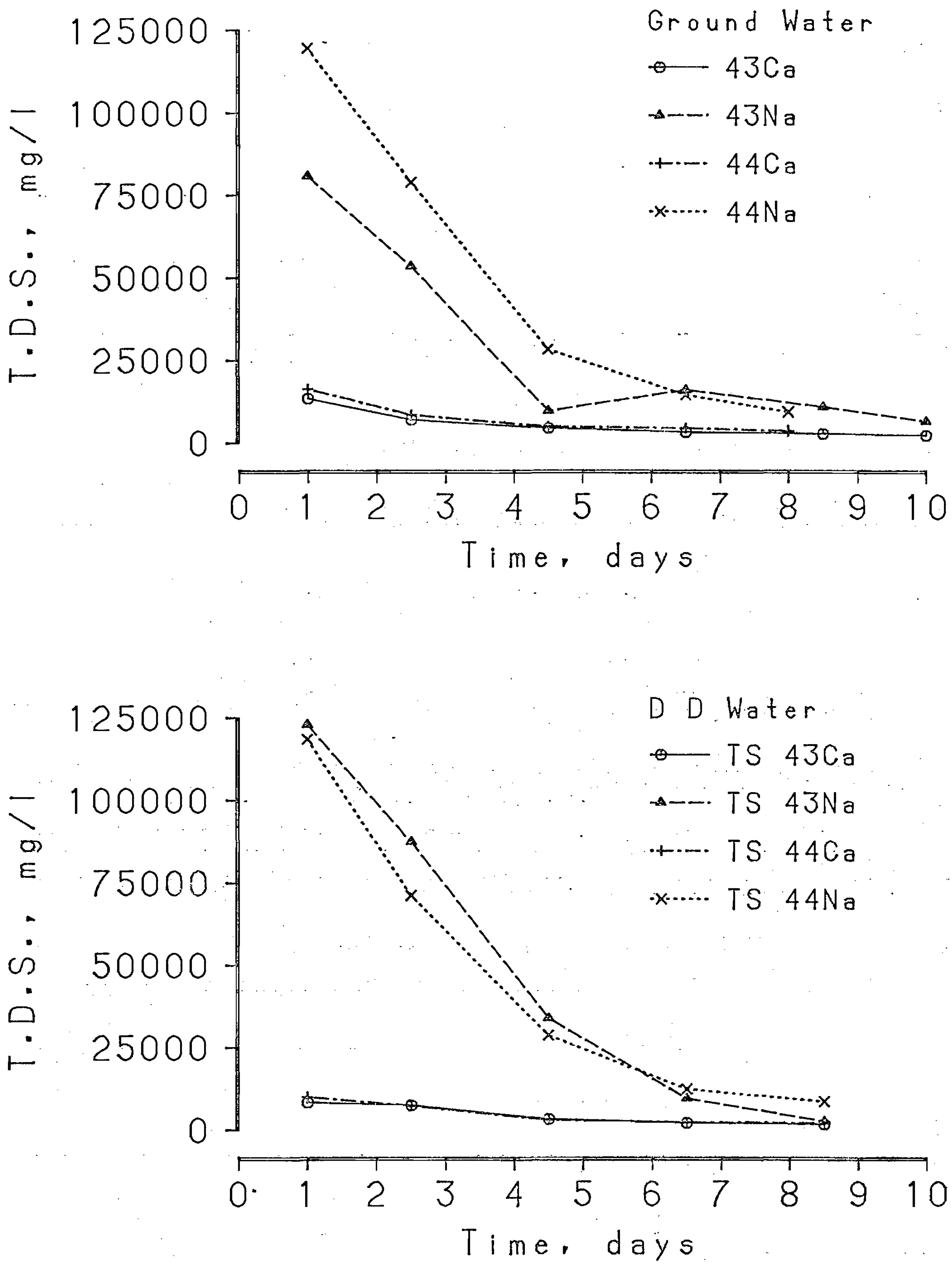
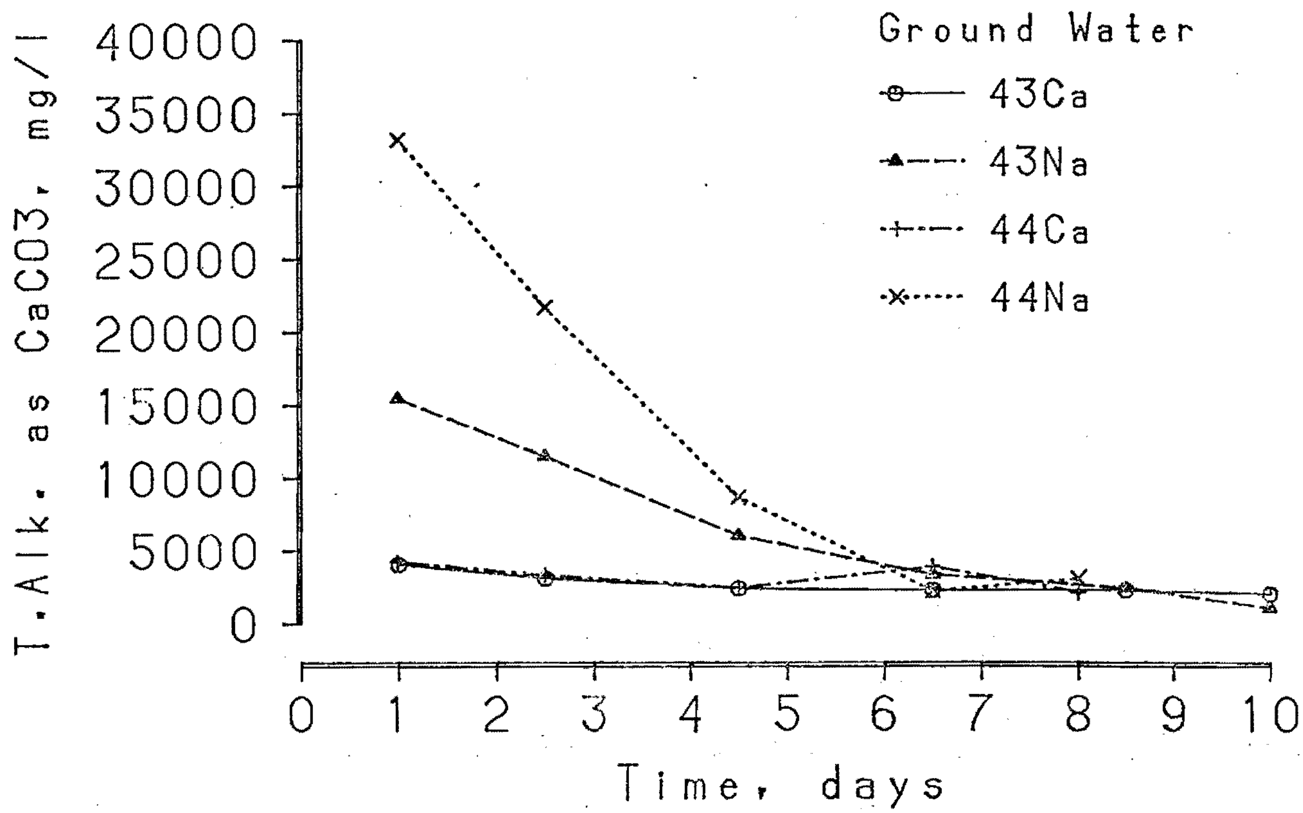


Figure 17. Total Dissolved Solids results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: → DDW topsoil → overburden → scrubber waste.



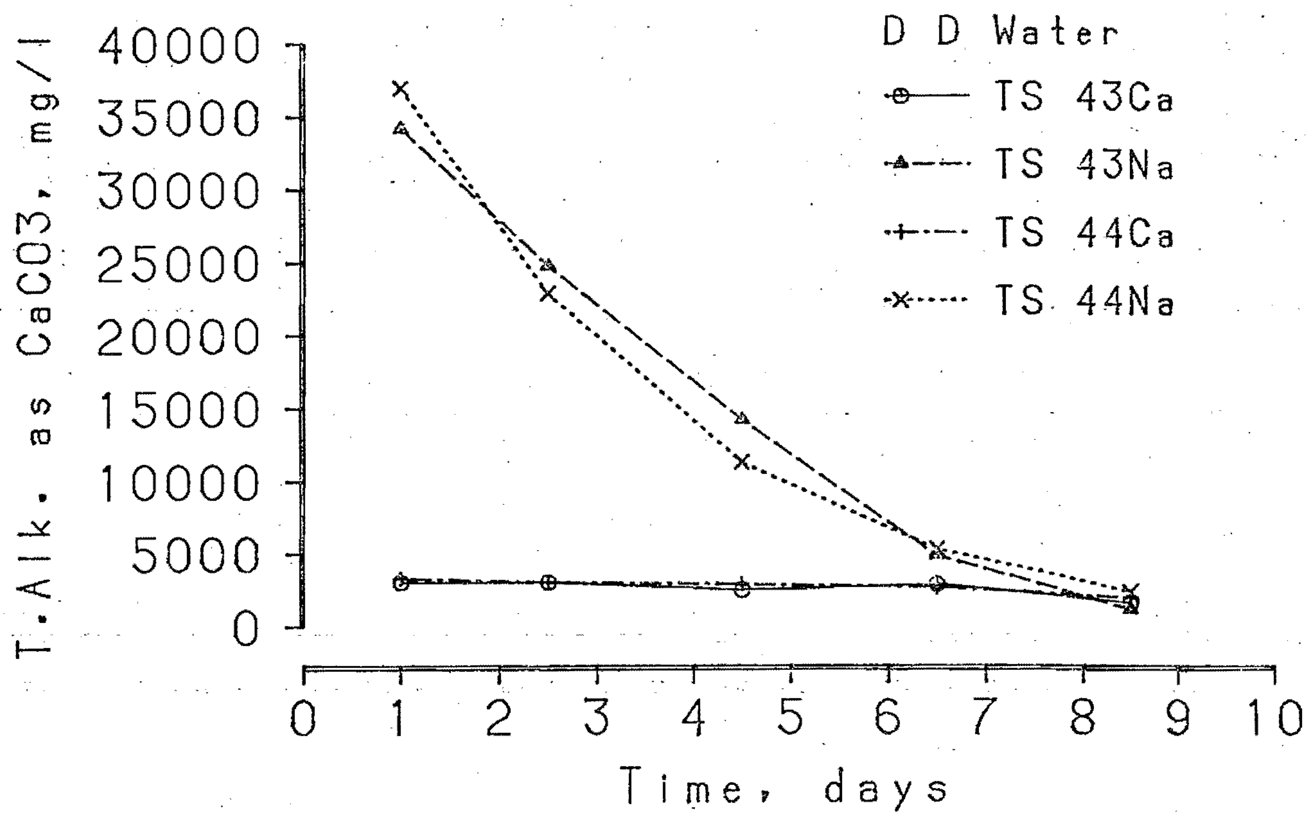


Figure 18. Alkalinity results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.

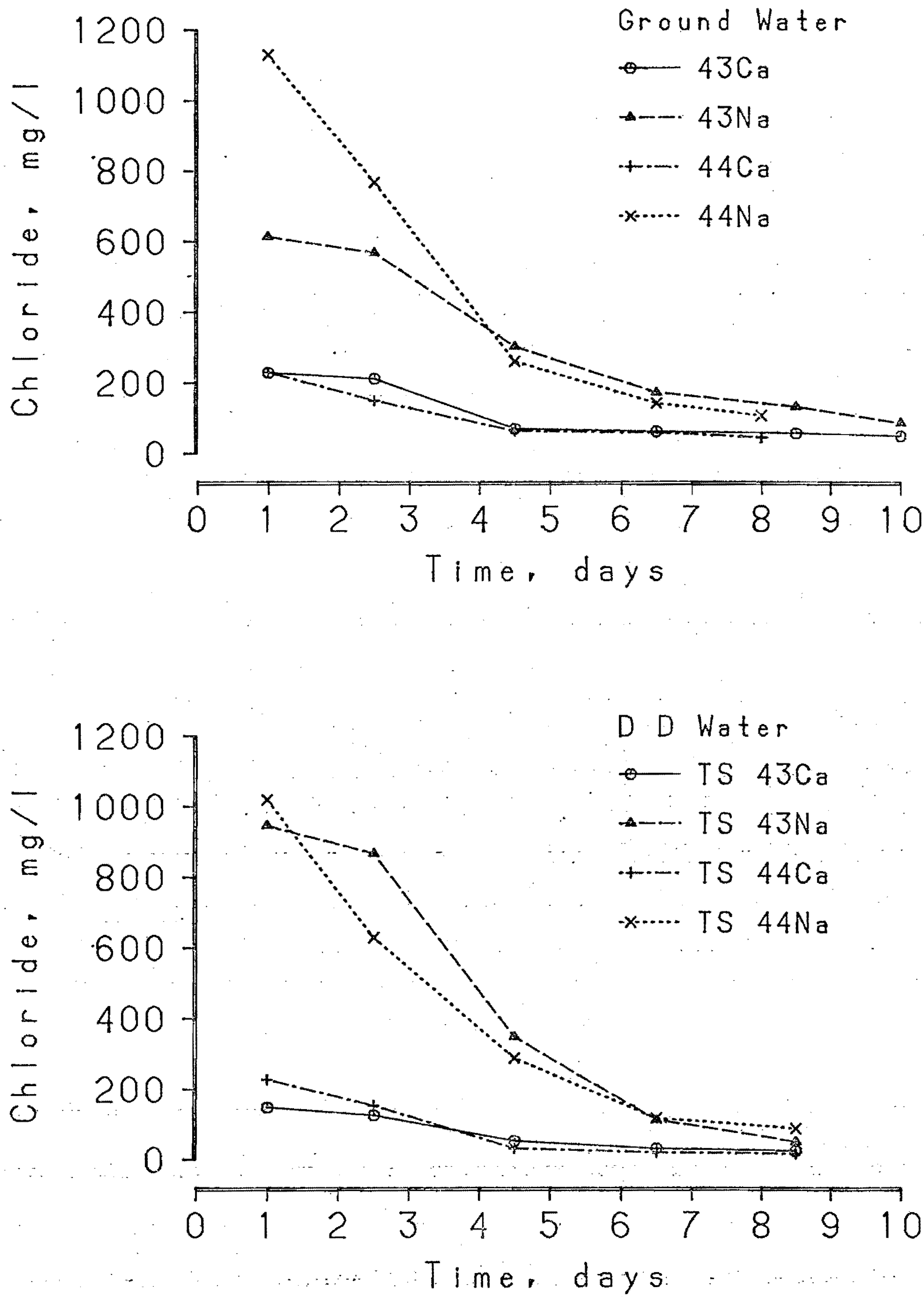
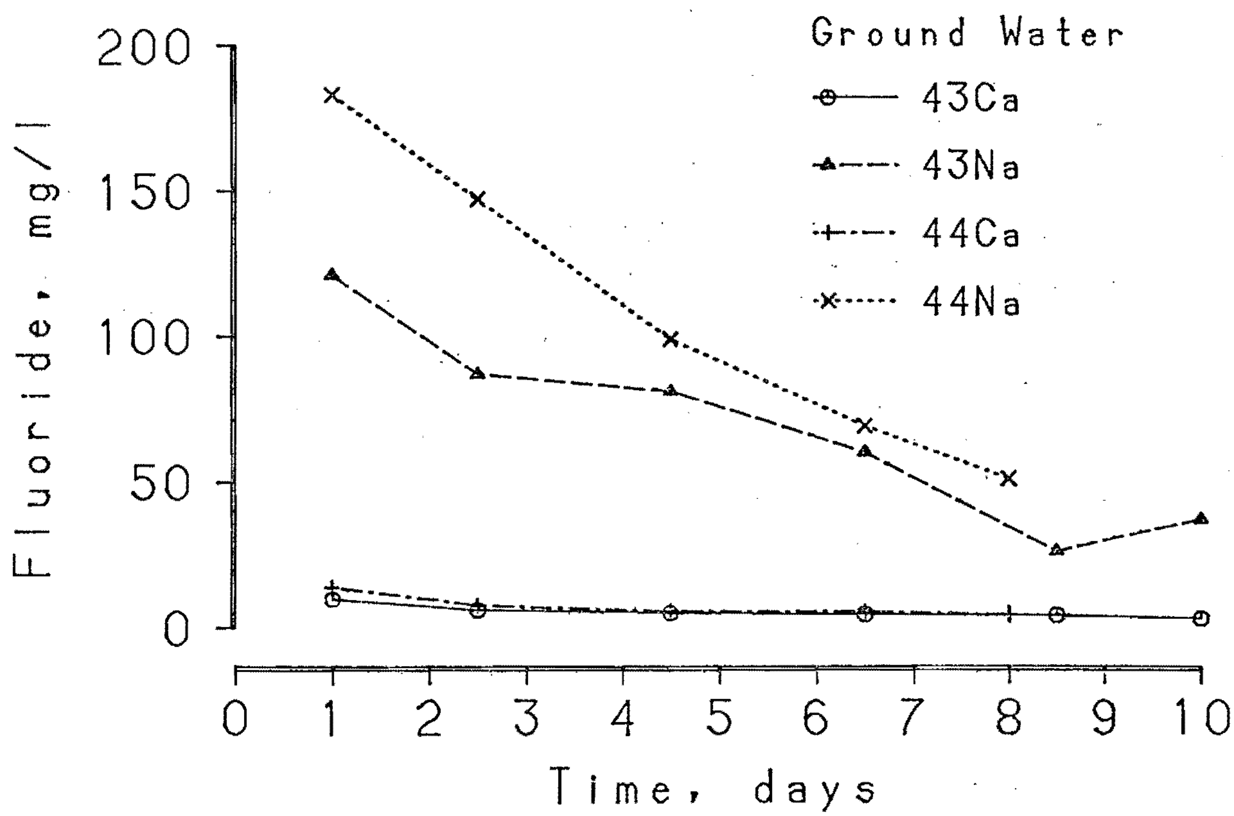


Figure 19. Chloride results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.



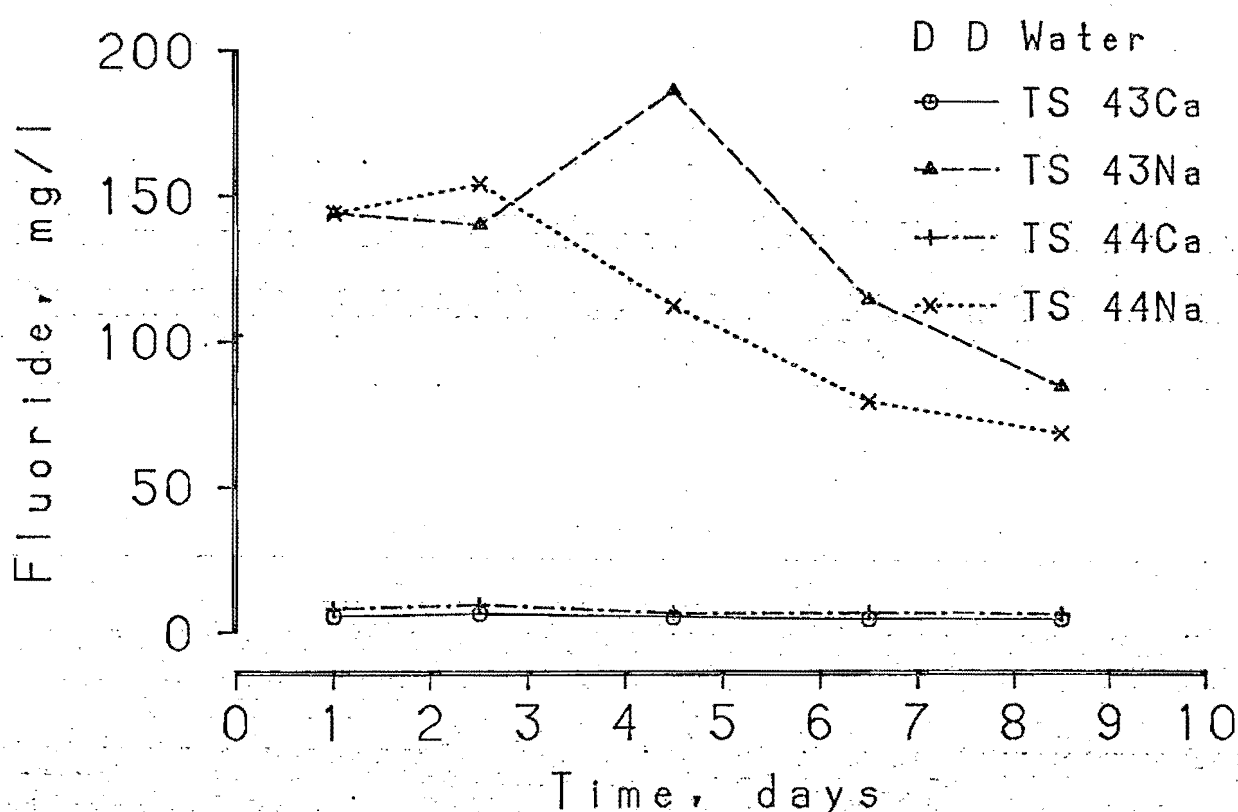


Figure 20. Fluoride results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.

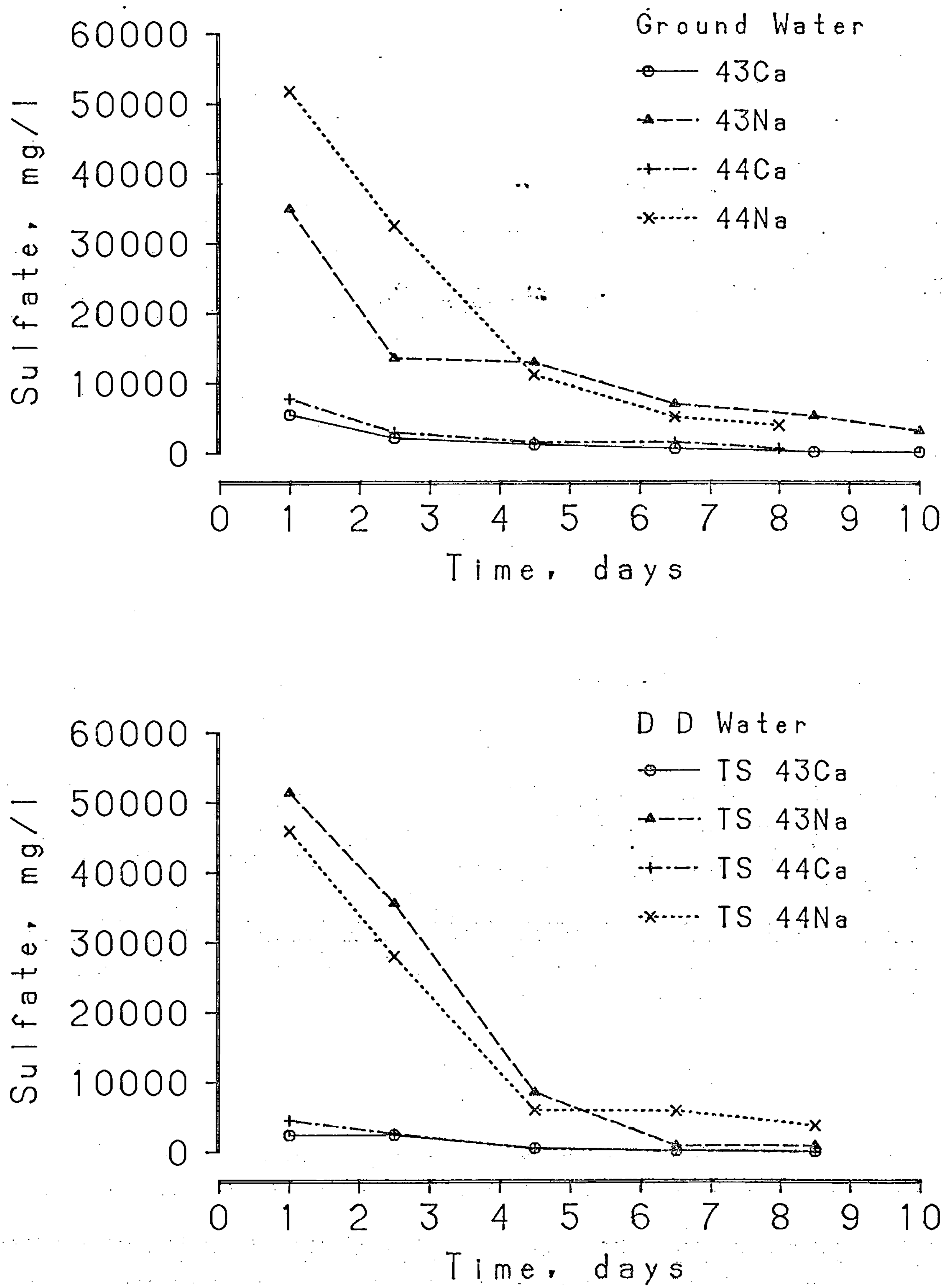


Figure 21. Sulfate results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.

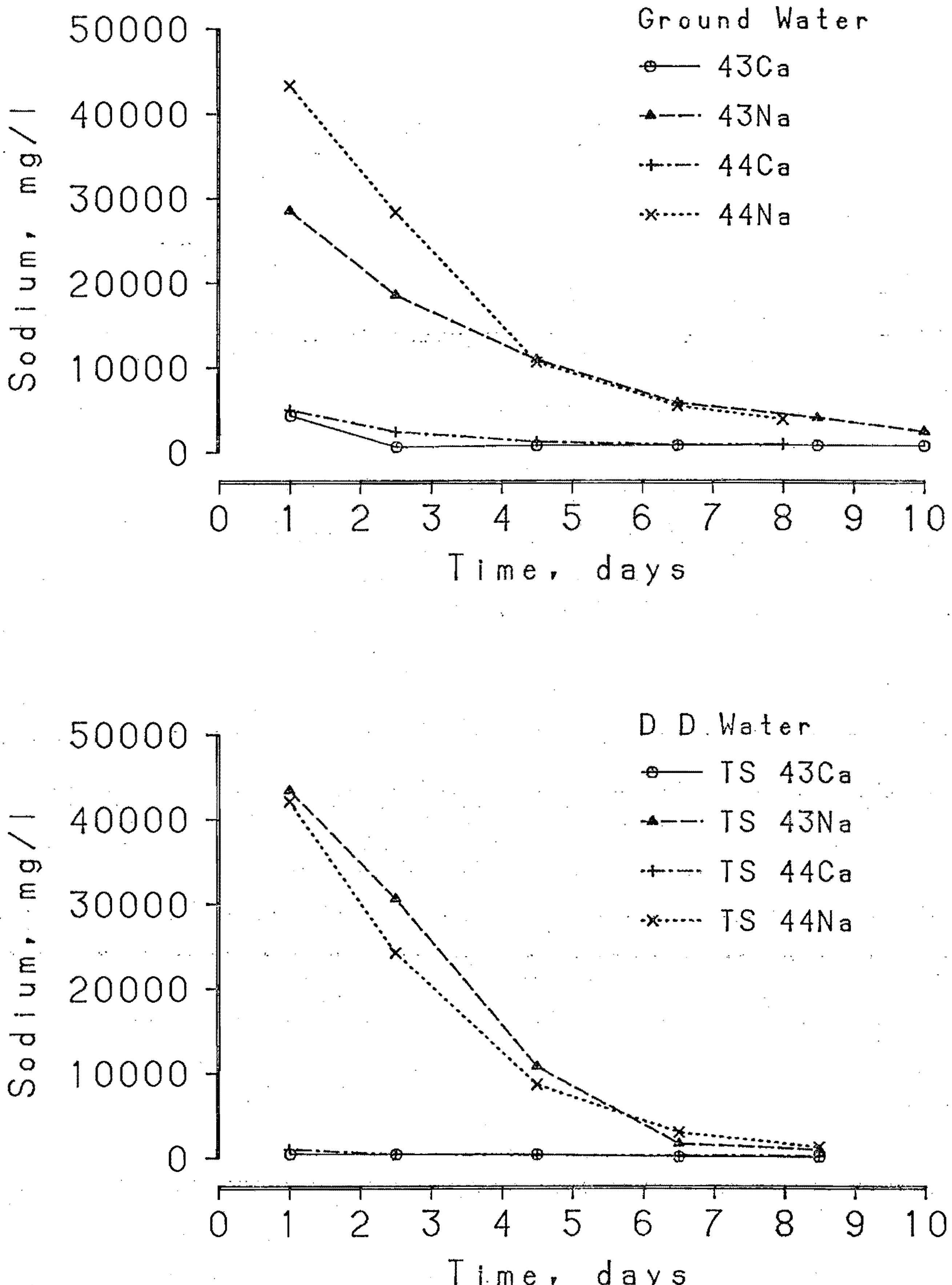


Figure 22. Sodium results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.

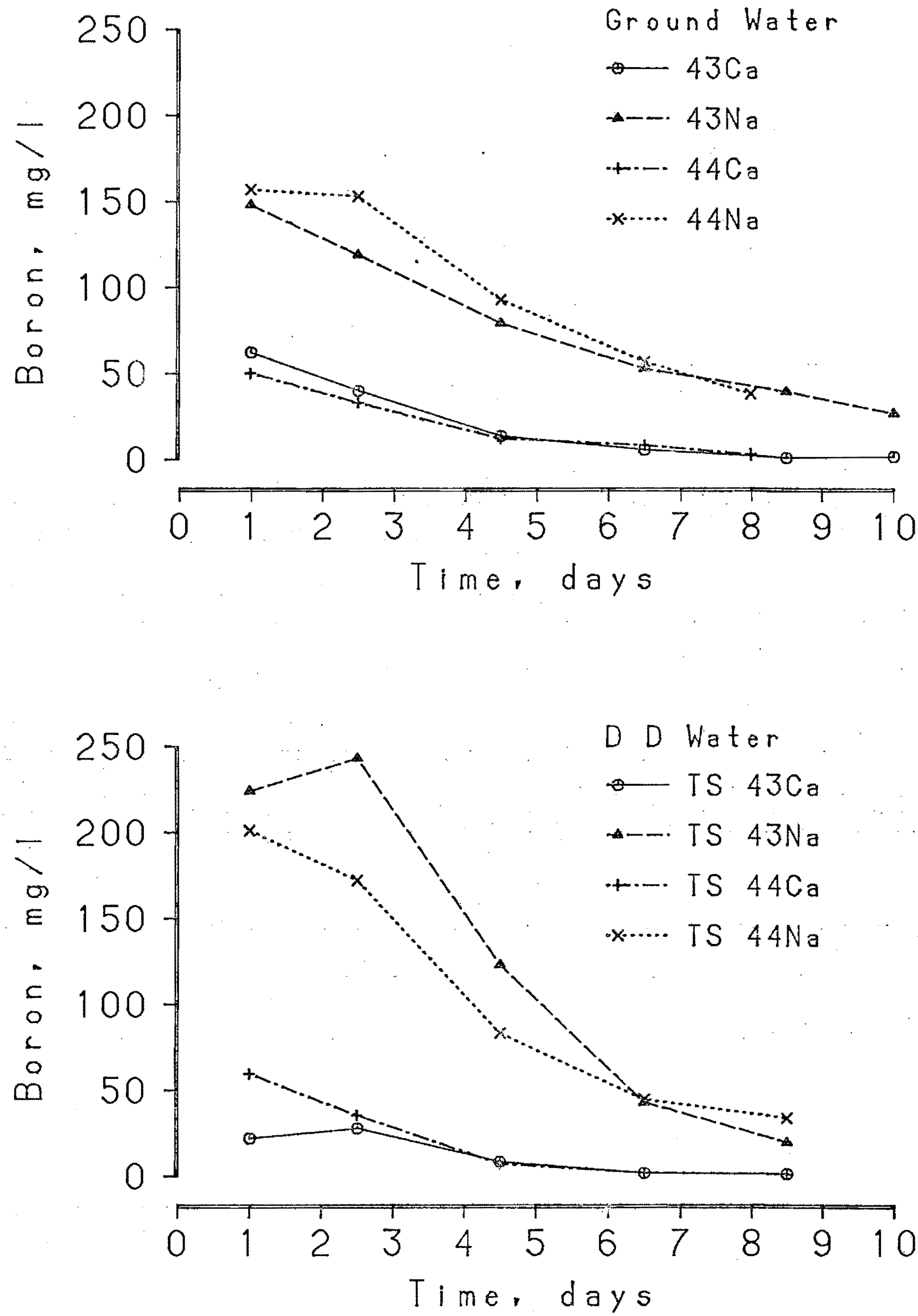


Figure 23. Boron results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.

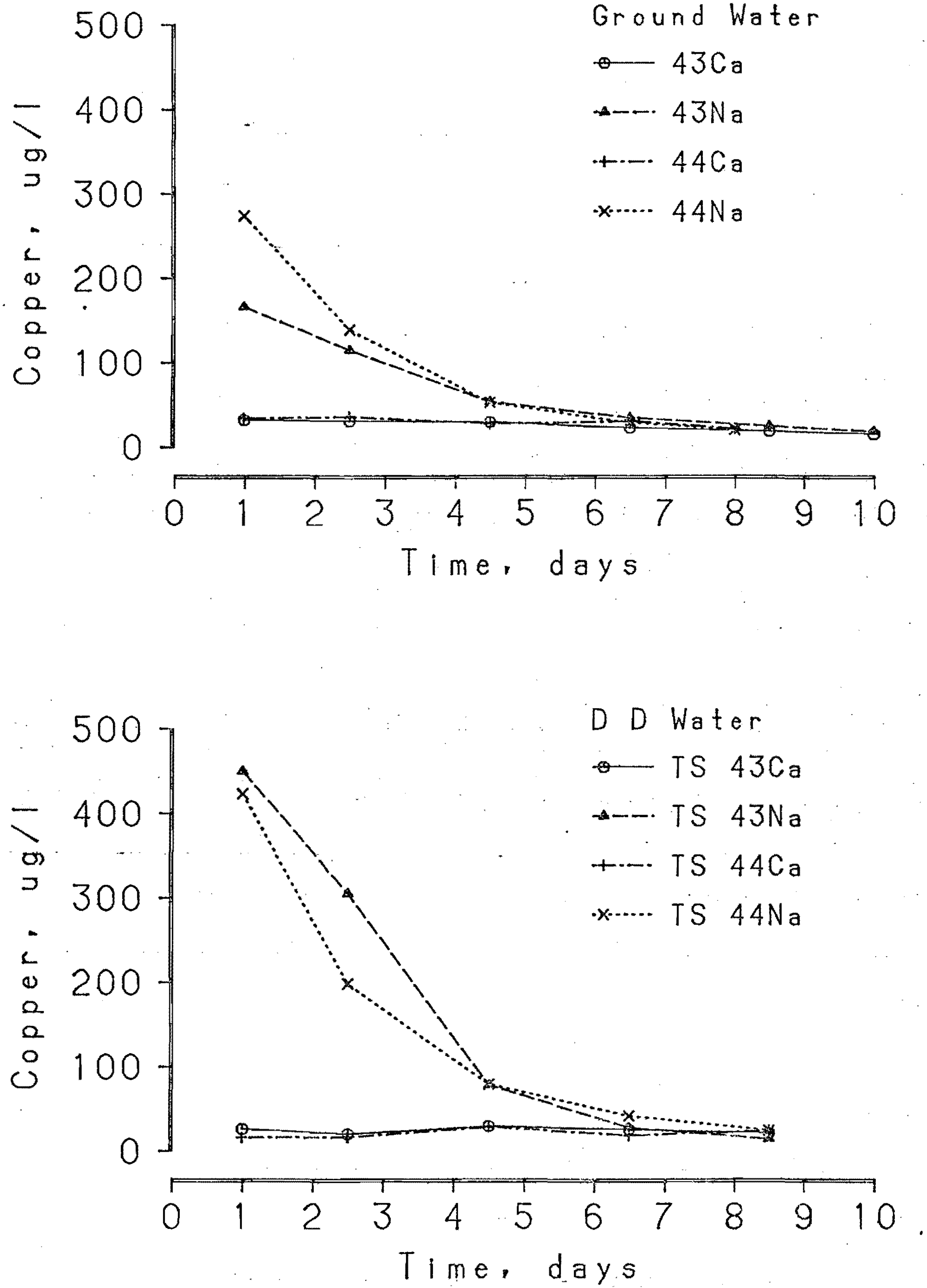
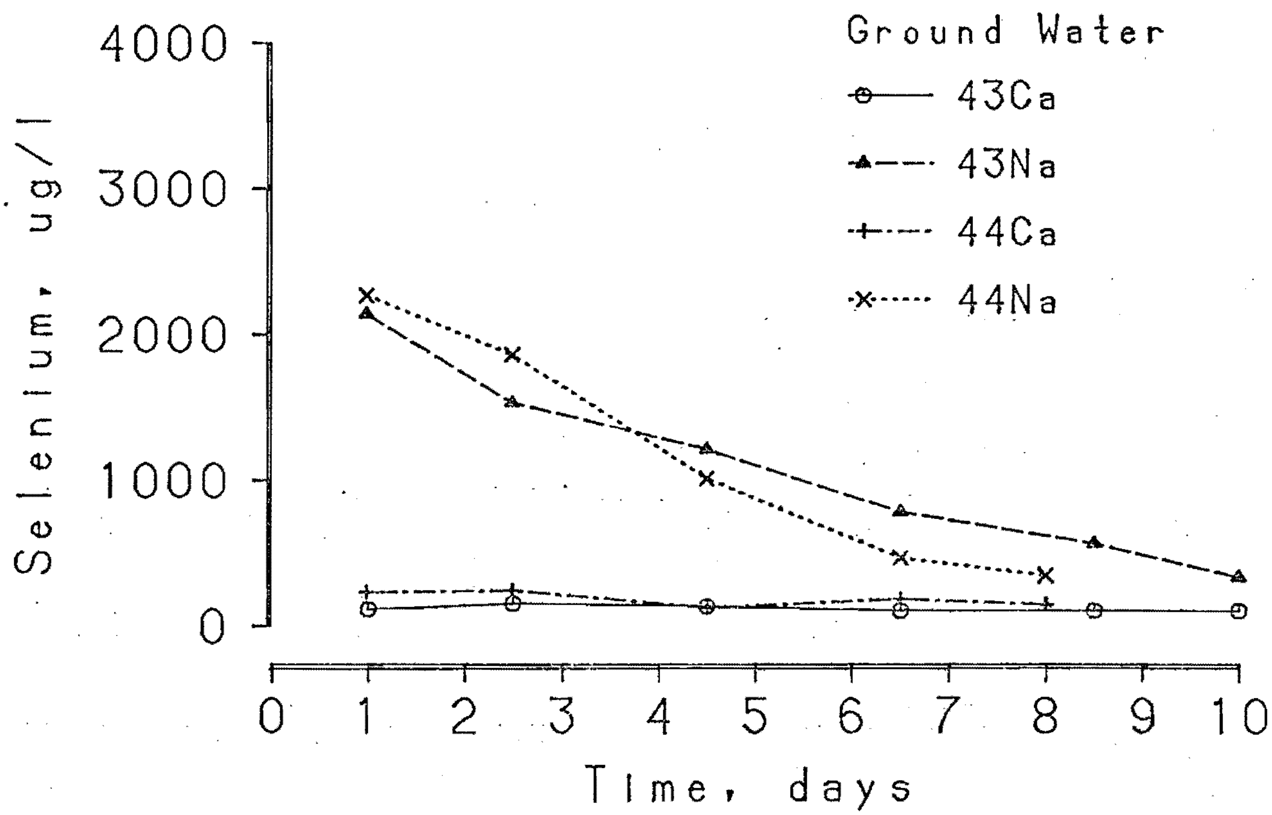


Figure 24. Copper results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.



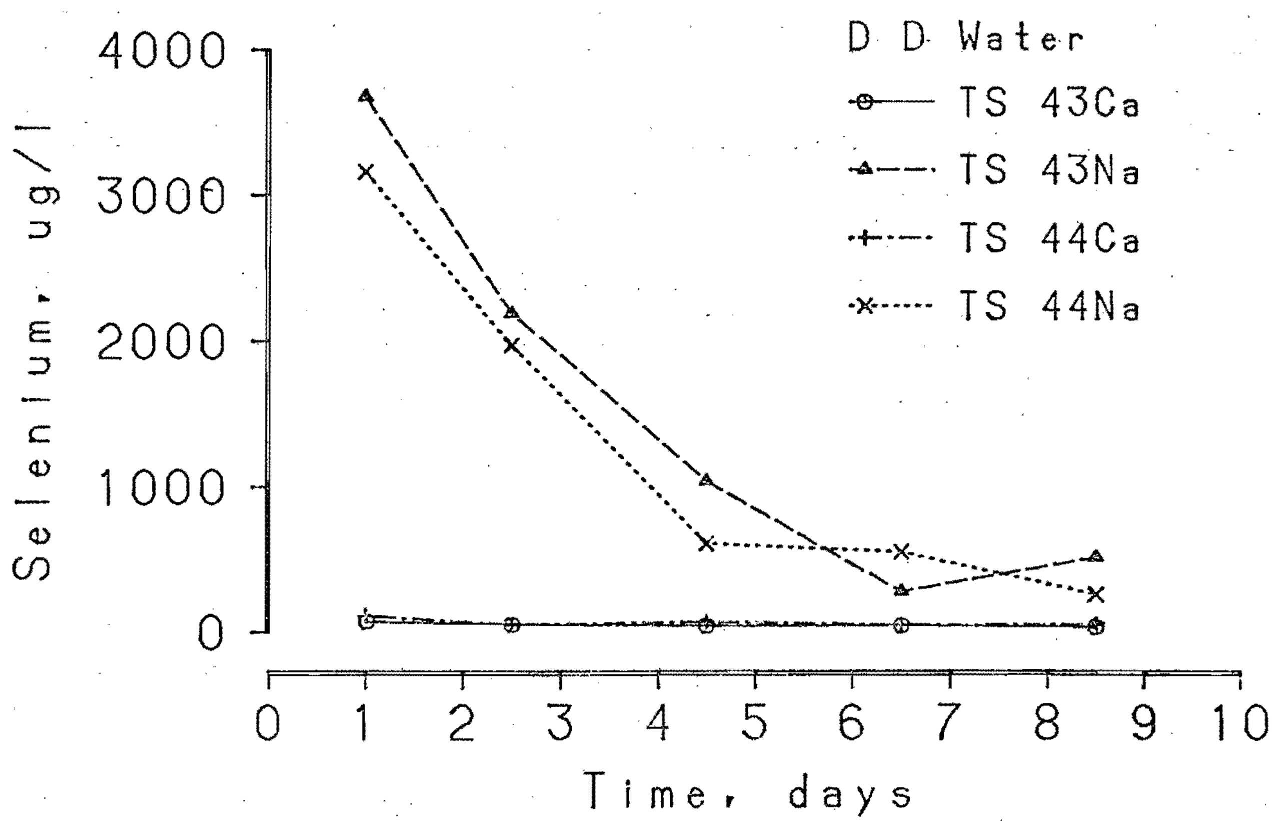
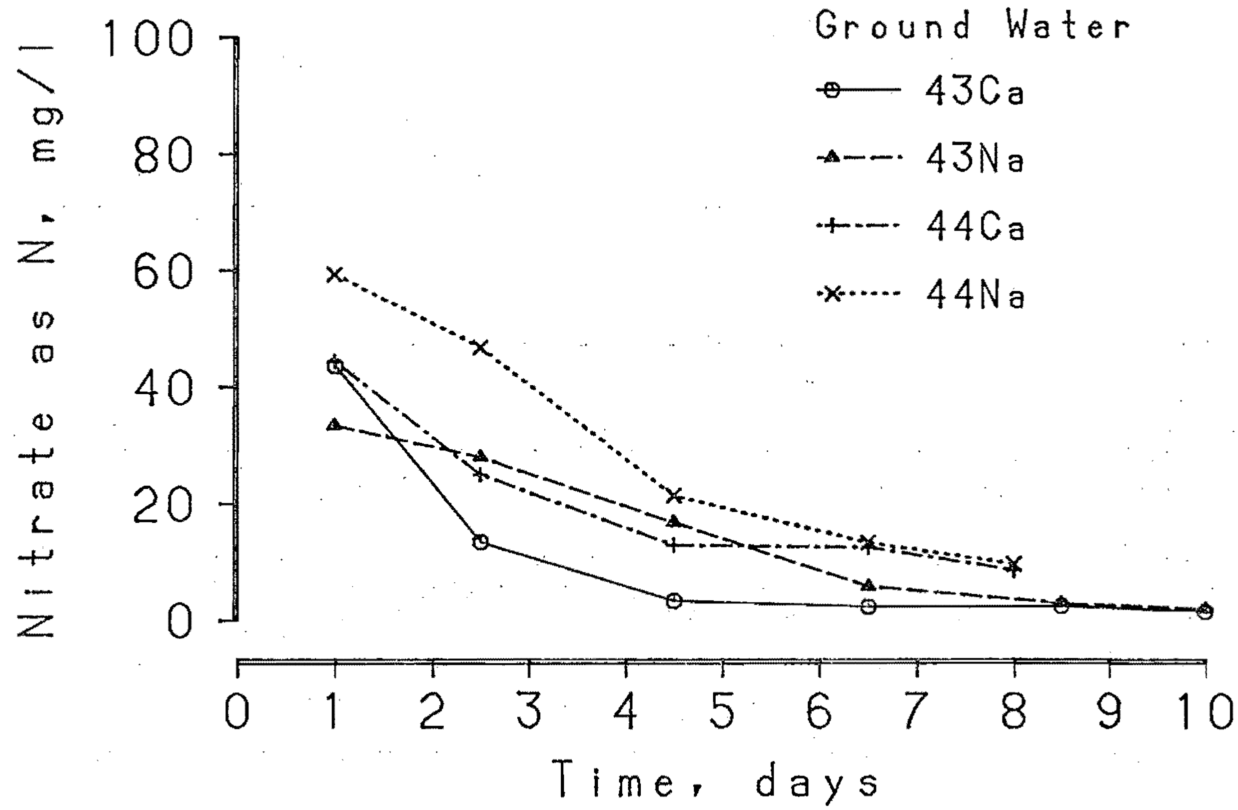


Figure 25. Selenium results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.

Ca scrubbing process as the Na SW released larger quantities of sulfate, nitrate, and nitrite than the Ca SW material (see Figures 21, 26, and 27). Scrubber process performance data would be needed to further evaluate this possibility. Chromium did not show trends similar to the other materials leached as there was very little difference between the Na SW and the Ca SW or the DDW and the GW except for the first two data points of the DDW → TS → OB 44 going through Ca SW (Figure 28). All other parameters measured were at the minimum detectable level of the instrumentation and/or no trend was observed.

The data for the final tier of the sequential schemes shown in Figure 3 is presented in Tables 27-42. Due to the tremendous amount of data generated in this part of the sequential scheme a summary table is presented (Table 43). Table 43 was generated by comparing "weighted mean" input leaching media and the final "weighted mean" leachate from each particular column. If an increase or decrease occurred between 10-30 percent, an I or d was used. If the increase or decrease was > 30 percent an I+ or d+ was used. For smaller number (< 100) some discretion was used as to the d, I, d+, or I+ notations. If the "weighted mean" concentrations did not change, a letter value was not assigned.

Nearly all of the final pH values were less than the initial pH values of the input media but usually only by a few tenths of a pH unit. Sample GW → OB 43 → Ca SW → OB 43 showed the largest drop in pH with a decrease of 1.6 pH unit. This sample also showed a rather unusual color pattern during the 9 day leaching period. The color progressed from a clear to red to dark brown. There were a variety of colors produced from all the columns as shown in Photograph 2 taken on day 6 of the final leaching process. Due to the high pH of the leaching media, the color



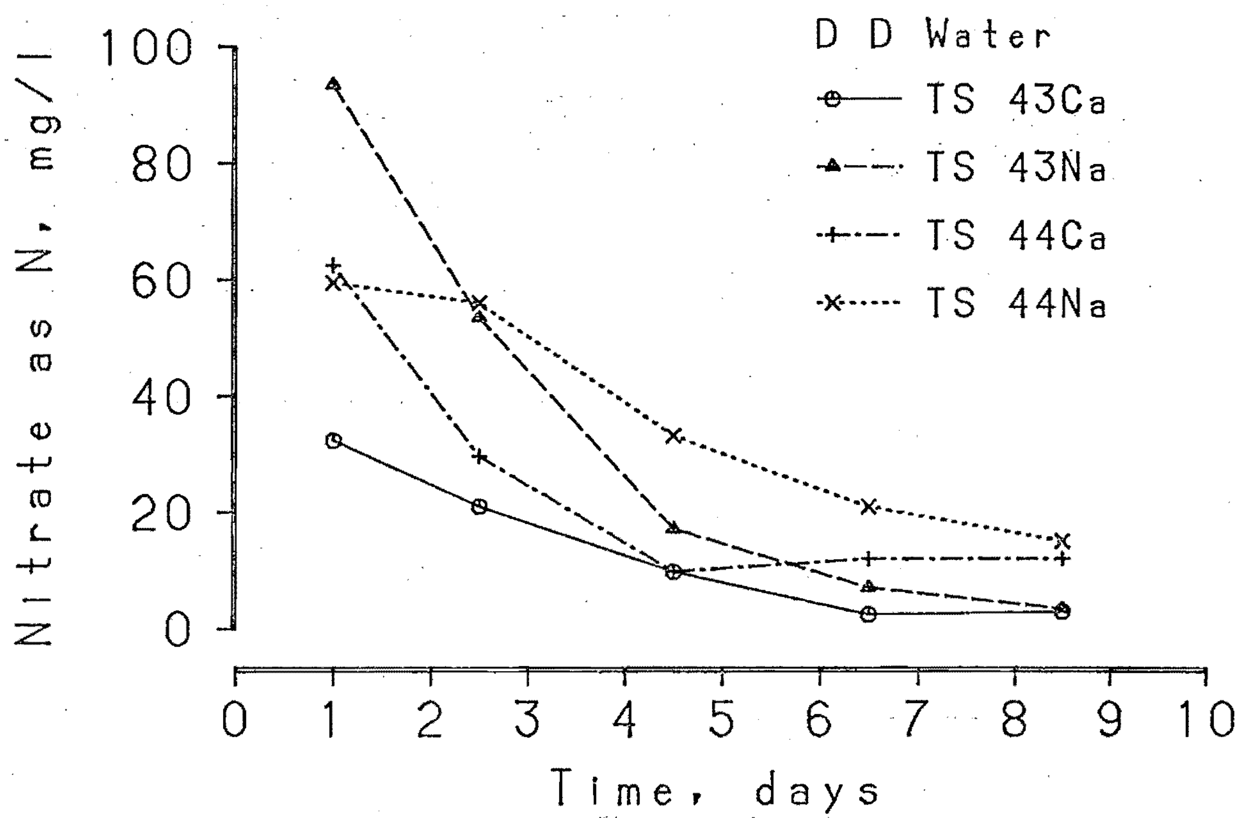


Figure 26. Nitrate results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.

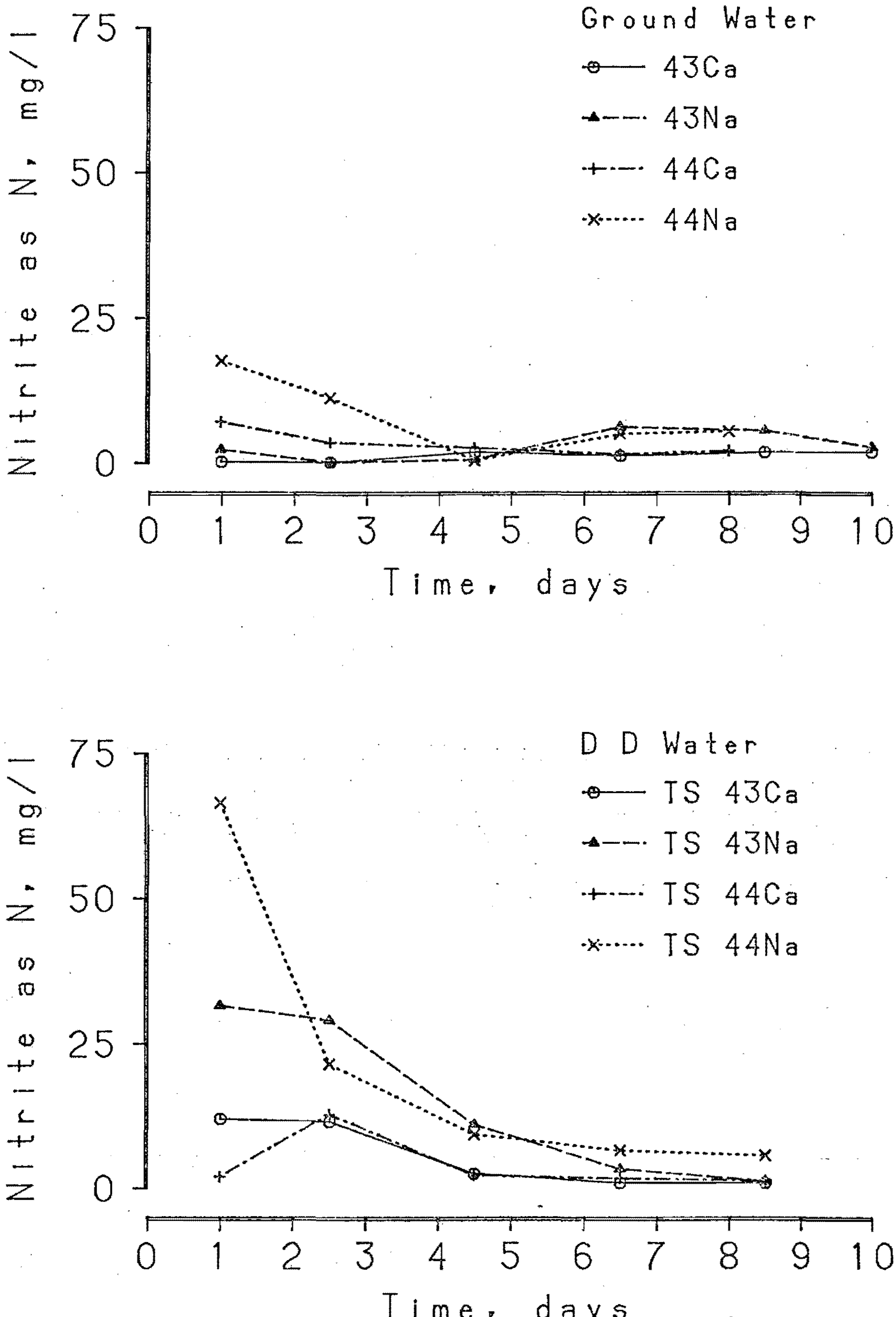
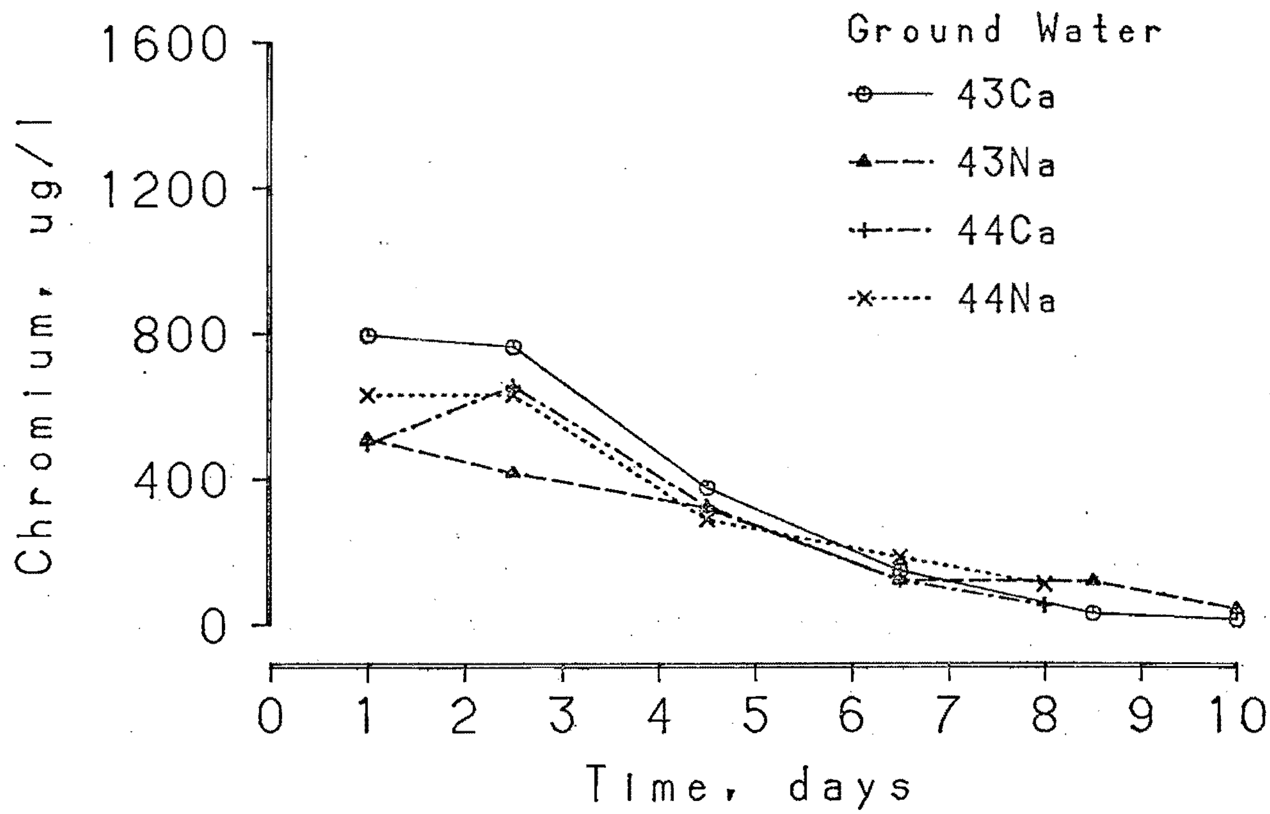


Figure 27. Nitrite results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.



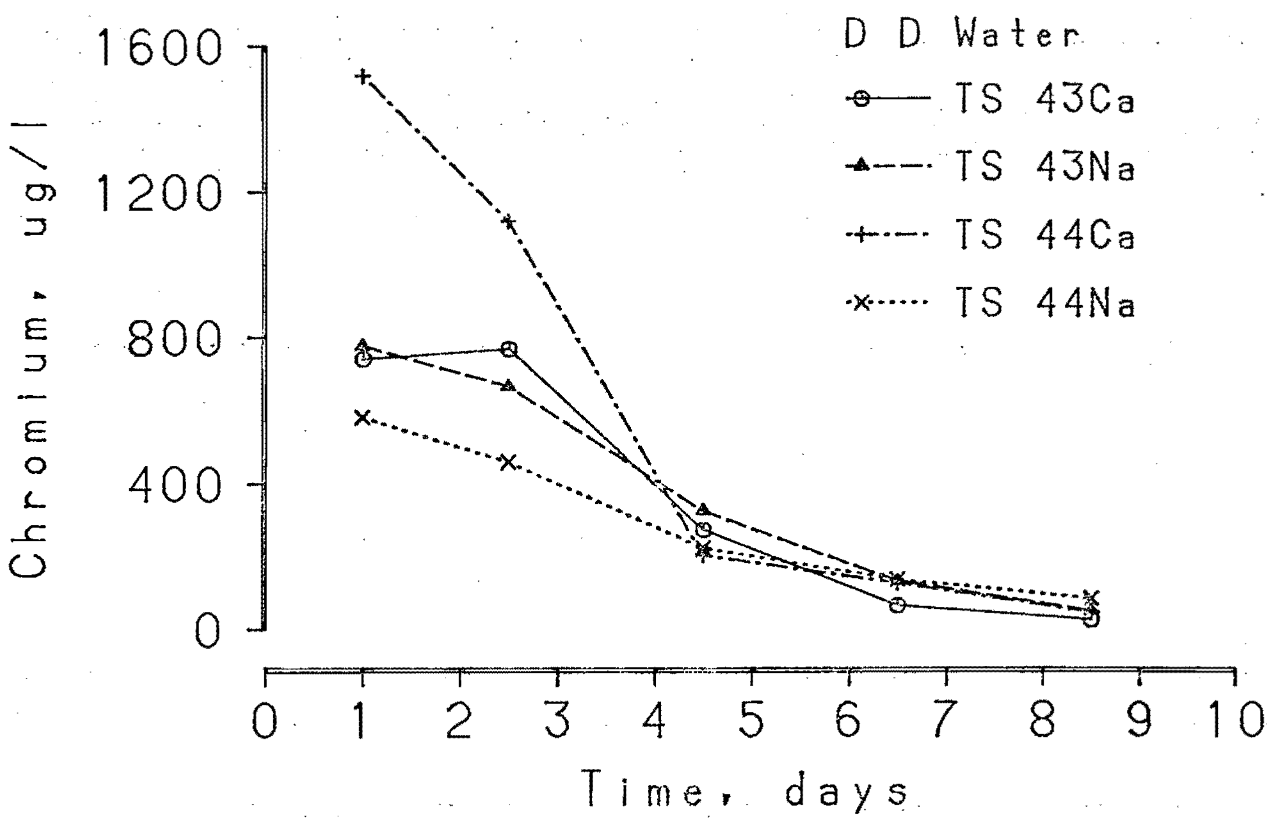


Figure 28. Chromium results from sequential columns. Upper: GW → overburden → scrubber waste. Lower: DDW → topsoil → overburden → scrubber waste.

Table 27. Sequential column experiment data: DDW → TS → OB 43 → Ca SW → OB 43.

DDW → topsoil → OB 081043 → Ca SW → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	11.8	6,120	3,352	654	97	3.9	1,650	11.6	4.4	348	<1	712	20	9.88	<4	<5	165	23	<1	0.7	<9	38	<6
2	11.7	5,420																					
3	11.3	4,340																					
Comp 2+3			3,220	456	102	5.0	930	14.1	5.4	282	6	709	23	9.28	<4	<5	146	22	6	0.3	<9	31	<6
4	11.6	4,500																					
5	11.7	4,660																					
Comp 4+5			2,814	418	90	4.5	1,390	9.7	5.8	185	8	684	22	10.3	<4	<5	109	24	<1	0.3	<9	34	<6
6	12.1	5,700																					
7	12.2	6,720																					
Comp 6+7			3,098	790	82	2.8	1,170	8.7	5.3	300	<1	724	18	10.2	<4	<5	28	20	2	2.0	<9	29	<6
8	12.3	7,500																					
9	9.0	3,620																					
Comp 8+9			2,958	958	75	3.3	1,220	7.1	4.9	243	10	706	28	11.1	<4	<5	19	24	5	0.5	<9	25	<6
INPUT**	12.3	10,800	3,976	2,550	65	5.2	931	10.8	4.5	767	4	263	13	10.7	<14	<4	318	24	<1	0.6	<11	60	14

**"Weighted Mean" of DDW → TS → OB 43 → Ca SW

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 28. Sequential column experiment data: DDW → TS → OB 43 → Ca SW → OB 44.

DDW → topsoil → OB 081043 → Ca SW → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.1	8,480	*	1,380	87	3.6	1,440	20.4	4.6	516	7	825	23	11.2	<4	<5	184	28	<1	0.5	<9	32	<6
2	12.0	8,540																					
3	12.4	8,970																					
Comp 2+3			4,212	1,570	71	5.3	1,220	20.4	5.1	559	1	812	18	10.6	<4	5	172	31	<1	0.2	<9	39	<6
4	12.4	8,970																					
5	12.2	8,660																					
Comp 4+5			4,000	1,660	75	4.4	1,400	16.7	5.3	532	14	773	22	12.2	<4	<5	168	26	<1	0.6	<9	40	<6
6	12.5	9,150																					
7	12.4	9,260																					
Comp 6+7			3,822	1,330	73	2.4	1,380	18.5	5.0	552	<1	772	27	11.6	<4	<5	120	22	<1	1.3	<9	32	<6
8	12.5	9,810																					
9	12.1	6,070																					
Comp 8+9			3,772	1,480	72	3.7	1,290	13.1	4.9	474	5	760	21	12.2	<4	<5	142	23	3	<0.2	<9	23	<6
INPUT**	12.3	10,800	3,976	2,550	65	5.2	931	10.8	4.5	767	4	263	13	10.7	<14	<4	318	24	<1	0.6	<11	60	14

*Insufficient sample.
**"Weighed Mean" of DDW → TS → OB 43 → Ca SW

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 29. Sequential column experiment data: DDW → TS → OB 44 → Ca SW → OB 43.

DDW → topsoil → OB 081044 → Ca SW → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/1	Total Alkalinity as $CaCO_3$ mg/1	Chloride mg/1	Fluoride mg/1	Sulfate mg/1	Nitrate as N, mg/1	Nitrite as N, mg/1	Calcium mg/1	Magnesium mg/1	Sodium mg/1	Arsenic µg/1	Boron mg/1	Beryllium µg/1	Cadmium µg/1	Chromium µg/1	Copper µg/1	Lead µg/1	Mercury µg/1	Nickel µg/1	Selenium µg/1	Zinc µg/1
Day 1	11.9	7,180	3,452	1,100	104	5.2	1,270	21.4	5.5	356	<1	814	2	11.1	<4	<5	285	24	<1	1.2	<9	28	<6
2	9.6	4,470																					
3	11.2	4,490																					
Comp 2+3			3,256	180	122	4.4	1,650	19.9	6.6	192	24	778	36	10.6	<4	<5	151	22	<1	2.6	<9	27	<6
4	11.7	4,670																					
5	11.8	5,400																					
Comp 4+5			2,970	606	88	2.9	1,400	15.7	6.8	189	9	752	18	12.7	<4	<5	156	20	<1	0.8	<9	30	<6
6	12.2	6,300																					
7	11.9	5,530																					
Comp 6+7			2,976	746	71	3.6	1,240	16.3	6.7	231	8	756	36	14.0	<4	<5	107	24	<1	17.3	<9	33	<6
8	12.0	6,970																					
9	12.2	7,150																					
Comp 8+9			3,366	947	66	5.0	1,220	14.9	6.6	322	14	768	20	15.0	<4	<5	107	23	<1	<0.2	<9	34	<6
INPUT**	12.4	11,700	4,137	2,700	68	7.2	1,090	19.5	4.3	742	12	362	20	15.1	<14	<4	461	21	<1	0.3	<11	44	11

**"Weighted Mean" of DDW → TS → OB 44 → Ca SW

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 30. Sequential column experiment data: DDW → TS → OB 44 → Ca SW → OB 44.

DDW → topsoil → OB 081044 → Ca SW → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.0	8,830	4,340	1,440	69	5.3	1,770	34.2	5.8	495	<1	896	17	15.0	<4	<5	298	42	<1	<0.2	<9	40	<6
2	11.7	8,250																					
3	12.3	8,850																					
Comp 2+3			5,060	1,050	75	4.8	2,620	51.3	6.2	513	4	1,480	17	12.8	<4	<5	288	26	<1	0.2	<9	51	<6
4	12.3	8,850																					
5	12.2	8,900																					
Comp 4+5			4,314	1,580	69	3.2	1,800	29.8	6.7	542	12	876	36	14.8	<4	<5	259	31	<1	0.8	<9	35	<6
6	12.4	8,570																					
7	12.3	8,840																					
Comp 6+7			4,044	1,340	68	3.4	1,580	22.8	6.2	518	<1	839	24	15.7	<4	<5	200	30	<1	3.2	<9	33	7
8	12.2	9,120																					
9	12.4	9,450																					
Comp 8+9			3,936	1,820	66	4.4	1,260	19.8	6.2	500	<1	817	20	16.8	<4	<5	220	21	3	<0.2	59	61	<6
INPUT**	12.4	11,700	4,137	2,700	68	7.2	1,090	19.5	4.3	742	12	362	20	15.1	<14	<4	461	21	<1	0.3	<11	44	11

**"Weighted Mean" of DDW → TS → OB 44 → Ca SW

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 31. Sequential column experiment data: DDW → TS → OB 43 → Na SW → OB 43.

DDW → topsoil → OB 081043 → Na SW → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.7	41,800	41,820	13,300	493	90	13,300	22.7	15.3	274	<1	13,400	600	105	<4	<5	582	260	8	0.5	63	1440	66
2	9.6	40,100																					
3	9.9	42,500																					
Comp 2+3			42,200	13,800	567	111	15,300	5.7	31.8	188	<1	13,100	470	118	<4	11	183	253	<1	1.0	67	1540	80
4	10.0	42,000																					
5	9.7	40,000																					
Comp 4+5			42,040	14,900	485	108	16,600	<0.1	44.3	100	3	16,600	470	132	<4	10	182	194	<1	0.9	54	1540	47
6	9.9	41,700																					
7	9.9	41,700																					
Comp 6+7			41,050	13,100	454	60	15,700	<0.1	40.0	75	1	14,500	730	125	<4	<5	138	200	27	2.3	64	1240	39
8	9.8	39,800																					
9	9.9	41,800																					
Comp 8+9			41,720	15,800	438	92	15,500	<0.1	37.8	67	1	13,900	630	130	<4	<5	135	214	14	0.7	66	1340	67
INPUT**	10.4	36,300	40,230	13,000	390	132	14,600	25.9	12.7	29	28	13,480	1070	116	<14	<4	330	132	<1	2.3	<11	1210	11

**"Weighted Mean" of DDW → TS → OB 43 → Na SW

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 32. Sequential column experiment data: DDW → TS → OB 43 → Na SW → OB 44.

DDW → topsoil → OB 081043 → Na SW → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.9	43,700	42,920	14,600	391	104	12,700	35.8	14.0	130	29	14,200	1010	110	<4	8	204	164	12	2.7	<9	1440	7
2	9.8	41,800																					
3	10.0	43,700																					
Comp 2+3			42,850	14,600	487	94	13,000	20.5	33.0	88	23	12,400	720	125	<4	5	187	157	<1	0.8	13	1340	9
4	10.0	42,500																					
5	9.8	41,100																					
Comp 4+5			42,320	15,100	442	111	16,300	<0.1	49.5	44	29	8,980	820	132	<4	<5	172	152	<1	0.8	38	1440	11
6	9.9	42,200																					
7	9.9	42,100																					
Comp 6+7			41,680	11,600	433	81	16,300	<0.1	47.8	49	15	15,300	584	124	<4	<5	140		13	17	24	1970	22
8	9.9	42,100																					
9	9.9	41,500																					
Comp 8+9			41,510	15,900	393	95	16,000	<0.1	46.8	37	17	14,400	1110	131	<4	<5	151	140	32	<0.2	40	1450	10
INPUT**	10.4	36,300	40,230	13,000	390	132	14,600	25.9	12.7	29	28	13,480	1070	116	<4	<4	330	132	<1	2.3	<11	1210	11

**"Weighted Mean" of DDW → TS → OB 43 → Na SW

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 33. Sequential column experiment data: DDW → TS → OB 44 → Na SW → OB 43.

DDW → topsoil → OB 081044 → Na SW → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.6	37,900	37,160	11,500	433	61	13,400	15.7	30.3	307	149	12,500		70.3	<4	10	146	220	17	0.7	113	710	63
2	9.4	35,800																					
3	9.9	39,200																					
Comp 2+3			37,760	11,200	529	76	13,700	<0.1	47.0	172	5	11,600	620	105	<4	9	131	313	<1	0.9	111	1030	154
4	9.9	38,800																					
5	9.8	37,100																					
Comp 4+5			38,220	13,900	455	33	15,600	<0.1	38.0	69	3	12,000	380	116	<4	<5	121	288	11	0.8	106	1030	149
6	9.9	37,100																					
7	9.7	37,000																					
Comp 6+7			36,760	11,000	440	32	15,900	<0.1	35.0	69	<1	12,900	450	112	<4	<5	106	345	<1	22	117	1140	188
8	9.8	36,500																					
9	9.9	37,200																					
Comp 8+9			36,790	14,200	429	16	14,000	<0.1	38.3	69	<1	12,900	630	116	<4	<5	116	353	14	0.7	157	930	196
INPUT**	10.4	34,500	36,960	12,500	337	106	13,600	30.3	15.0	35	27	11,790	770	92.4	<14	<4	253	104	<1	1.7	<11	1020	29

**"Weighted Mean" of DDW → TS → OB 44 → Na SW

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 34. Sequential column experiment data: DDW → TS → OB 44 → Na SW → OB 44.

DDW → topsoil → OB 081044 → Na SW → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.9	40,200	38,360	13,900	389	81	12,800	40.0	20.5	53	24	13,300	600	89.3	<4	<5	149	139	<1	2.0	51	660	<6
2	9.8	38,600																					
3	10.0	40,300																					
Comp 2+3			38,960	13,400	407	51	11,500	10.5	46.0	65	45	15,400	320	99.1	<4	7	136	147	<1	1.7	15	1080	25
4	10.0	39,900																					
5	9.8	37,600																					
Comp 4+5			38,130	13,800	411	64	14,600	1.5	43.0	44	30	12,800	660	102	<4	<5	118	135	<1	0.8	30	1080	9
6	10.0	38,200																					
7	9.8	38,000																					
Comp 6+7			36,470	11,700	351	63	16,200	<0.1	42.0	34	21	13,700	600	104	<4	5	90	128	<1	0.6	10	1080	<6
8	9.9	38,200																					
9	10.0	37,400																					
Comp 8+9			36,430	14,100	342	57	15,000	<0.1	48.5	43	11	12,800	610	86.8	<4	<5	109	113	<1	1.8	45	930	<6
INPUT**	10.4	34,500	36,960	12,500	337	106	13,600	30.3	15.0	35	27	11,790	770	92.4	<14	<4	253	104	<1	1.7	<11	1020	29

**"Weighted Mean" of DDW → TS → OB 44 → Na SW

DDW: Doubly deionized water
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 35. Sequential column experiment data: GW → OB 43 → Ca SW → OB 43.

GW → OB 081043 → Ca SW → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.1	7,760	4,889	716	169	4.6	2,330	16.3	5.2	271	24	1,410	2	22.6	<14	<4	529	18	<1	8.0	<11	121	<5
2	9.6	5,340																					
3	9.1	5,750																					
Comp 2+3			4,760	396	166	4.1	2,550	16.1	5.9	212	64	1,070	3	18.9	<14	<4	110	25	32	6.0	<11	230	14
4	9.5	5,360																					
5	11.5	5,580																					
Comp 4+5			5,048	495	170	7.3	1,880	8.9	8.1	140	21	1,110	8	26.4	<14	<4	90	115	18	0.4	63	120	99
6	12.0	6,580																					
7	12.0	6,190																					
Comp 6+7			4,610	805	178	5.1	2,190	6.4	6.1	61	23	1,110	6	25.8	<14	<4	100	64	17	0.2	31	131	54
8	12.3	7,770	4,218	1,060	98	4.9	1,550	5.7	5.3	97	4	1,210	18	21.0	<14	<4	143	13	<1	0.6	<11	171	15
9	11.3	5,290																					
INPUT**	12.6	12,900	4,812	2,590	106	5.0	1,310	7.8	1.2	639	59	988	5	17.5	<14	<4	340	26	4	3.4	<11	118	17

**"Weighted Mean" of GW → OB 43 → Ca SW

GW: Groundwater
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 36. Sequential column experiment data: GW → OB 43 → Ca SW → OB 44.

GW → OB 081043 → Ca SW → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.5	10,760	5,542	1,590	100	4.9	2,180	21.9	5.6	453	13	1,810	3	25.3	<14	<4	650	27	<1	11.0	<11	211	<5
2	12.3	10,090																					
3	12.5	10,970																					
Comp 2+3			6,362	1,380	103	4.8	2,630	37.1	5.9	515	<1	1,510	<1	23.3	<14	<4	553	124	<1	3.0	<11	302	6
4	12.4	10,000																					
5	12.5	10,800																					
Comp 4+5			5,940	1,380	102	4.4	2,480	23.0	6.0	435	2	1,410	1	20.8	<14	<4	522	24	2	2.5	<11	211	8
6	12.5	10,600																					
7	12.5	10,400																					
Comp 6+7			5,395	1,380	102	5.0	1,830	16.6	5.4	409	12	1,310	36	22.3	<14	<4	539	25	<1	1.2	<11	131	5
8	12.5	10,000	4,915	1,440	89	3.9	1,670	12.4	5.6	344	6	1,300	19	21.0	<14	<4	466	18	<1	2.6	<11	91	11
9	11.2	4,420																					
INPUT**	12.6	12,900	4,812	2,590	106	5.0	1,310	7.8	1.2	639	59	988	5	17.5	<14	<4	340	26	4	3.4	<11	118	17

**"Weighted Mean" of GW → OB 43 → Ca SW

GW: Groundwater
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 37. Sequential column experiment data: GW → OB 44 → Ca SW → OB 43.

GW → OB 081044 → Ca SW → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.1	8,440	5,212	816	104	4.7	2,570	22.8	4.8	247	8	2,010	6	16.4	<14	<4	461	23	<1	4.0	<11	101	<5
2	12.3	9,280																					
3	12.4	10,600																					
Comp 2+3			5,836	1,230	94	4.8	2,590	20.1	4.9	457	3	1,280	3	12.3	<14	<4	284	39	3	15.0	<11	101	10
4	12.3	9,730																					
5	12.4	9,650																					
Comp 4+5			5,810	1,120	104	3.9	2,450	18.1	4.9	413	17	1,310	3	18.6	14	<4	225	20	<1	5.0	<11	121	<5
6	12.4	10,300																					
7	12.4	10,600																					
Comp 6+7			5,832	1,032	108	3.5	2,520	17.0	5.0	421	12	1,310	4	18.6	<14	<4	215	27	<1	2.0	<11	121	<5
8	12.2	8,800	5,092	759	98	4.2	2,520	16.8	5.2	146	16												
INPUT**	12.6	15,500	6,639	3,230	99	6.6	2,410	18.3	2.9	787	29	1,760	5	19.4	<14	<4	350	31	<1	3.5	<11	182	16

**"Weighted Mean" of GW → OB 44 → Ca SW

GW: Groundwater
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 38. Sequential column experiment data: GW → OB 44 → Ca SW → OB 44.

GW → OB 081044 → Ca SW → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	12.5	11,450	6,412	1,550	114	5.0	2,800	31.5	5.0	535	12	2,510	6	19.2	<14	<4	431	26	6	1.0	<11	101	<5
2	12.4	11,200																					
3	12.5	12,600																					
Comp 2+3			6,970	1,600	93	5.0	2,900	36.9	5.1	457	1	1,560	5	13.3	<14	<4	418	29	<1	17.0	<11	80	<5
4	12.5	11,500																					
5	12.5	11,700																					
Comp 4+5			6,530	1,460	82	3.4	2,720	26.8	5.6	497	32	1,610	<1	17.2	<14	<4	391	28	<1	8.0	<11	141	<5
6	12.5	11,800																					
7	12.5	11,300																					
Comp 6+7			6,475	1,380	98	3.5	2,760	25.3	5.7	453	53	1,510	3	18.6	<14	<4	385	27	<1	1.0	<11	101	63
8	9.5	9,090																					
INPUT**	12.6	15,500	6,639	3,230	99	6.6	2,410	18.3	2.9	787	29	1,760	5	19.4	<14	<4	350	31	<1	3.5	<11	182	16

**"Weighted Mean" of GW → OB 44 → Ca SW

GW: Groundwater
OB: Overburden, core #081043 or #081044
Ca SW: Calcium based scrubber waste
Comp: Composite sample.

Table 39. Sequential column experiment data: GW → OB 43 → Na SW → OB 43.

GW → OB 081043 → Na SW → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/1	Total Alkalinity as $CaCO_3$ mg/1	Chloride mg/1	Fluoride mg/1	Sulfate mg/1	Nitrate as N, mg/1	Nitrite as N, mg/1	Calcium mg/1	Magnesium mg/1	Sodium mg/1	Arsenic µg/1	Boron mg/1	Beryllium µg/1	Cadmium µg/1	Chromium µg/1	Copper µg/1	Lead µg/1	Mercury µg/1	Nickel µg/1	Selenium µg/1	Zinc µg/1
Day 1	9.5	32,800	33,620	5,560	458	90	19,800	29.5	15.5	297	9	10,900	760	94.5	<14	<4	254	107	11	6.0	53	1210	18
2	9.3	30,300																					
3	9.3	34,700																					
Comp 2+3			35,160	5,300	519	65	17,300	7.0	23.0	238	2	9,480	300	89.4	<14	<4	205	167	4	4.0	65	806	115
4	9.5	34,400																					
5	9.6	34,400																					
Comp 4+5			37,320	5,980	493	91	18,000	6.0	8.0	152	3	10,000	910	90.9	<14	<4	184	254	4	0.8	141	1420	172
6	9.5	35,300																					
7	9.7	35,200																					
Comp 6+7			37,230	6,210	535	86	19,100	<0.1	6.3	117	2	9,800	810	92.4	14	<4	205	277	15	1.0	185	810	239
8	9.7	35,500	37,230	6,500	484	73	19,600	<0.1	10.0	85	9	11,200	710	121.	17	<4	191	284	30	1.8	110	1940	231
9	9.7	36,100																					
INPUT**	10.1	30,200	25,480	6,170	302	66	11,060	14.0	3.0	28	29	10,600	840	94.7	<14	<4	249	62	3	2.3	<11	1050	13

**"Weighted Mean" of GW → OB 43 → Na SW

GW: Groundwater
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 40. Sequential column experiment data: GW → OB 43 → Na SW → OB 44.

GW → OB 081043 → Na SW → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/1	Total Alkalinity as $CaCO_3$ mg/1	Chloride mg/1	Fluoride mg/1	Sulfate mg/1	Nitrate as N, mg/1	Nitrite as N, mg/1	Calcium mg/1	Magnesium mg/1	Sodium mg/1	Arsenic µg/1	Boron mg/1	Beryllium µg/1	Cadmium µg/1	Chromium µg/1	Copper µg/1	Lead µg/1	Mercury µg/1	Nickel µg/1	Selenium µg/1	Zinc µg/1
Day 1	9.8	33,600	34,930	6,110	460	74	21,300	36.0	17.5	97	48	11,900	510	106	<14	<4	289	74	<1	14.0	<11	1120	<5
2	9.8	32,700																					
3	9.8	32,700																					
Comp 2+3			36,140	6,050	353	83	15,900	31.5	23.5	58	79	10,000	710	84.1	<14	<4	255	63	19	30.0	<11	1210	15
4	9.7	34,600																					
5	9.8	35,500																					
Comp 4+5			37,940	5,950	407	83	16,600	15.0	25.5	65	54	9,920	400	84.1	15	<4	215	70	19	9.0	<11	1210	18
6	9.7	35,600																					
7	9.8	36,700																					
Comp 6+7			37,550	6,745	480	110	18,600	4.3	25.7	65	45	9,900	300	110	<14	<4	203	75	<1	4.0	29	1210	12
8	9.8	37,000	37,070	6,520	425	91	14,800	<0.1	27.5	61	20	10,900	510	101	<14	5	209	119	13	7.4	<11	1210	31
9	9.8	36,100																					
INPUT**	10.1	30,200	25,200	6,170	302	66	11,060	14.0	3.0	28	29	10,600	840	94.7	<14	<4	249	62	3	2.3	<11	1050	13

**"Weighted Mean" of GW → OB 43 → Na SW

GW: Groundwater
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 41. Sequential column experiment data: GW → OB 44 → Na SW → OB 43.

GW → OB 081044 → Na SW → OB 081043

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	9.7	41,700	44,630	9,810	552	116	25,500	31.5	29	188	7	15,600	540	106	<14	<4	334	202	43	1.0	41	1520	64
2	9.8	38,400																					
3	9.8	47,200																					
Comp 2+3			47,090	11,300	552	99	21,800	9.0	36	158	6	12,000	1020	89.4	17	<4	304	172	<1	1.0	60	1220	97
4	9.8	40,300																					
5	9.9	42,400																					
Comp 4+5			47,680	11,850	536	92	22,900	<0.1	38.5	108	3	12,400	1120	120	14	<4	311	185	45	0.6	91	1520	110
6	9.8	45,100																					
7	9.8	44,600																					
Comp 6+7			48,040	11,900	564	95	21,700	<0.1	45.5	84	7	12,800	1520	120	17	<4	255	210	31	1.0	122	820	135
8	9.9	44,300	47,820	11,800	553	75	21,800	<0.1	45.0	81	2	15,300	730	112	<14	6	224	240	32	0.6	44	2170	138
INPUT**	10.7	39,300	44,900	12,180	432	107	18,390	28.5	6.6	35	15	16,400	940	100	<14	4	369	87	<1	2.9	<11	1150	16

**"Weighted Mean" of GW → OB 44 → Na SW

GW: Groundwater
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 42. Sequential column experiment data: GW → OB 44 → Na SW → OB 44.

GW → OB 081044 → Na SW → OB 081044

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
Day 1	10.0	40,900	46,620	11,800	419	111	17,400	39.5	30.5	93	30	16,400	750	93.4	<14	<4	335	105	23	4.0	<11	2030	<5
2	9.9	41,400																					
3	9.9	43,500																					
Comp 2+3			47,940	10,850	470	113	24,000	36.0	39.0	89	53	12,400	1020	89.4	<14	<4	265	98	37	2.0	17	1050	29
4	9.9	42,200																					
5	10.0	43,000																					
Comp 4+5			48,420	11,850	471	84	20,000	13.7	43.3	55	44	12,800	1320	117	15	<4	292	102	46	5.0	27	1830	18
6	9.9	44,700																					
7	9.9	44,900																					
Comp 6+7			47,800	12,100	524	84	16,700	4.5	45.5	62	13	13,100	920	119	<14	<4	236	87	27	2.8	17	1830	9
8	10.0	44,400	47,320	12,000	519	87	21,800	<0.1	48.7	41	17	14,900	1170	114	<14	6	230	146	33	1.6	<11	1840	39
INPUT**	10.7	39,300	44,900	12,180	432	107	18,390	28.5	6.6	35	15	16,400	940	100	<14	4	369	87	<1	2.9	<11	1150	16

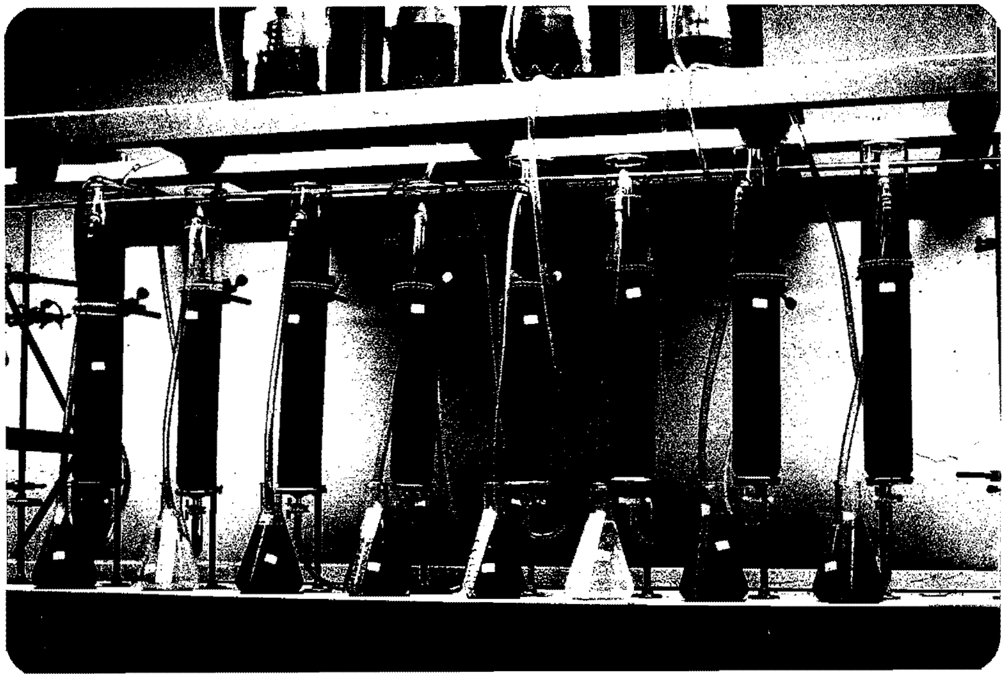
**"Weighted Mean" of GW → OB 44 → Na SW

GW: Groundwater
OB: Overburden, core #081043 or #081044
Na SW: Sodium based scrubber waste
Comp: Composite sample.

Table 43. Summary table[a] of data generated in the final tier of sequential schemes A and B (Figure 3) using "weighted mean" values for input media and final leachate concentrations.

Leachate		Chemical Parameters																						
		pH	EC µmhos/cm at 25°C	TDS, mg/l	Total Alkalinity as $CaCO_3$, mg/l	Chloride, mg/l	Fluoride, mg/l	Sulfate, mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium, mg/l	Magnesium, mg/l	Sodium, mg/l	Arsenic, µg/l	Boron, mg/l	Beryllium, µg/l	Cadmium, µg/l	Chromium, µg/l	Copper, µg/l	Lead, µg/l	Mercury, µg/l	Nickel, µg/l	Selenium, µg/l	Zinc, µg/l
DDW → TS → OB 43 → Ca SW	→ OB 43		d+	d	d+	I		I			d+		I+	I				d+				d	d	
	→ OB 44		d		d+	I		I+	I		d		I+	I				d+				d	d	
DDW → TS → OB 44 → Ca SW	→ OB 43		d+	d	d+	I		I			d+		I+					d+					d	
	→ OB 44		d+		d+		d	I+	I		d		I+					d+						
DDW → TS → OB 43 → Na SW	→ OB 43		I			I	d		d+	I+	I+	d		d+				d+	I+			I	I	I
	→ OB 44		I			I	d		d	I	I			d				d+	I			I	I	
DDW → TS → OB 44 → Na SW	→ OB 43					I+	d+		d+	I+	I+			d				d+	I+			I+		I+
	→ OB 44					I	d+		d+	I+	I		I	d				d+	I			I		
GW → OB 43 → Ca SW	→ OB 43	d	d+		d	I		I+			d+	d	I					d+	I				I	I
	→ OB 44		d	I	d+			I+	I		d	d	I					I+	I				I	
GW → OB 44 → Ca SW	→ OB 43		d+	d	d+						d+		d					d					d	
	→ OB 44		d		d+			I	I		d+							I					d	
GW → OB 43 → Na SW	→ OB 43		I	I+		I+	I	I+		I	I+			d				d	I+				I	I+
	→ OB 44		I	I		I+	I	I+		I+	I	I		d					I				I	
GW → OB 44 → Na SW	→ OB 43		I			I		I	d	I+	I+		d					d	I+			I	I	I
	→ OB 44		I			I		I		I	I	I	d					d	I	I			I+	

[a]An I or d was used to indicate a change of 10 to 30 percent between the "weighted mean" input media and the final "weighted mean" leachate. If the increase or decrease was > 30 percent an I+ or d+ was used. If the "weighted mean" numbers were small (< 100) some discretion was used. If no change occurred a letter value was not assigned.



Photograph 2. Upflow columns from part of sequential column experiment. Columns shown are the final tier from the groundwater series (Figure 3A). Note the variety of colors produced. Input media are shown in the 20 liter reservoirs in the upper part of the photograph.

may be due to organic matter (Appendix, Table 45). Conductivities of the Ca SW based leaching medias all decreased for both the DDW and GW. All but two of the Na SW based medias increased in conductivity going through OB 43 and OB 44. No general trend was evident with regard to total dissolved solids. All Ca SW based media alkalinities decreased for both DDW and GW with no increase or decrease occurring for the Na SW based medias going through OB 43 and OB 44. The chloride and sulfate data indicated either an increase or no change. Fluoride decreased in some of the DDW based medias and increased in two of the GW based medias. It should be noted that all of the leachate fluoride concentrations from the Na SW were much greater than the USEPA drinking water standard for fluoride (Sawyer and McCarty 1978) (Appendix, Table 46).

For nitrate and nitrite the Na SW based media showed a decrease in nitrate and an increase in nitrite through OB 43 and OB 44 (possible chemical or biological conversion occurring). Most all combined levels of nitrate and nitrite exceeded the USEPA 10 mg/l standard for public water supplies (Sawyer and McCarty 1978). Calcium decreased in all cases for Ca SW based media for both DDW and GW and increased for Na SW based media. Although there were some changes in the magnesium and sodium concentrations, no trend was evident. Arsenic concentrations decreased moderately or remained the same as the input leaching media except for the DDW → Ca SW based leaching media which increased going through OB 43 and OB 44. All of the Na SW based leachates exceeded the USEPA drinking water standard for arsenic of 50 μg/l (Appendix, Table 46).

Boron, beryllium and cadmium concentrations showed no increases or decreases when the media were put through OB 43 and OB 44. The boron levels were always higher in the Na SW based media than the Ca SW media. This may again point to the Na scrubbing process being more efficient than the Ca scrubbing process. The beryllium and cadmium concentrations were generally less than the detectable level of the atomic absorption instrument. Chromium concentrations decreased in almost all cases. The concentrations were all much higher than the established USEPA drinking water standard (Appendix, Table 46). The copper concentrations for the Na SW based media increased going through OB 43 and OB 44 for both the DDW and GW. The Na SW based media was again always higher than the Ca SW media with regard to the copper concentrations. Lead concentrations were generally very low or near the minimum detectable level of the atomic absorption instrument (< 1 μg/l). Although no trend for mercury was observable, many of the mercury concentrations were above the established USEPA drinking water standard of 2 μg/l (Appendix, Table 46). Most nickel concentrations were low or near the detection level of < 11 μg/l except for the DDW-Na SW based leaching media going through OB 43 and 44 (Tables 31-34, Figure 29).

No trend was observed for selenium concentrations except that the Na SW based media leachates were higher than the Ca SW based media leachates (Figure 30). In all cases the USEPA drinking water standard (Appendix, Table 46) of 10 μg/l was exceeded.

Zinc concentrations were at or near the minimum detectable limit of < 5 μg/l except for the DDW and GW-Na SW based media going through OB 43 (Figure 31).

It should be noted that copper, nickel, and zinc concentrations were always higher in the Na SW based media leachates and the color of these leachates was also much darker (Photograph 3).

Photograph 3. Upflow columns. Leftmost eight columns are the final tier in the DDW sequential column experiment (Figure 3B). The color of the leachate produced is visible in the upper third of each column.

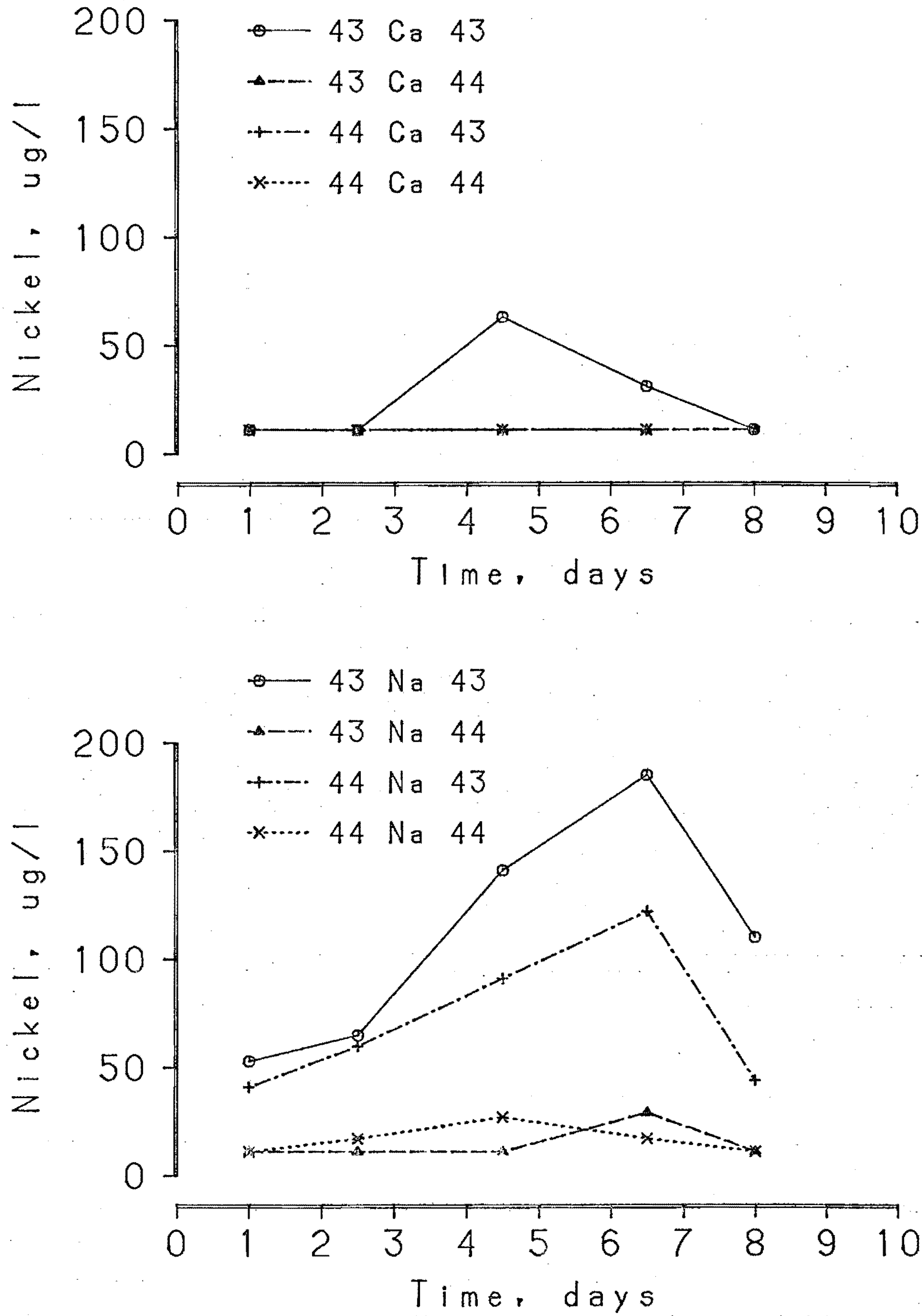


Figure 29. Nickel results from sequential columns. Upper: GW → overburden → calcium scrubber waste → overburden. Lower: GW → overburden → sodium scrubber waste → overburden.

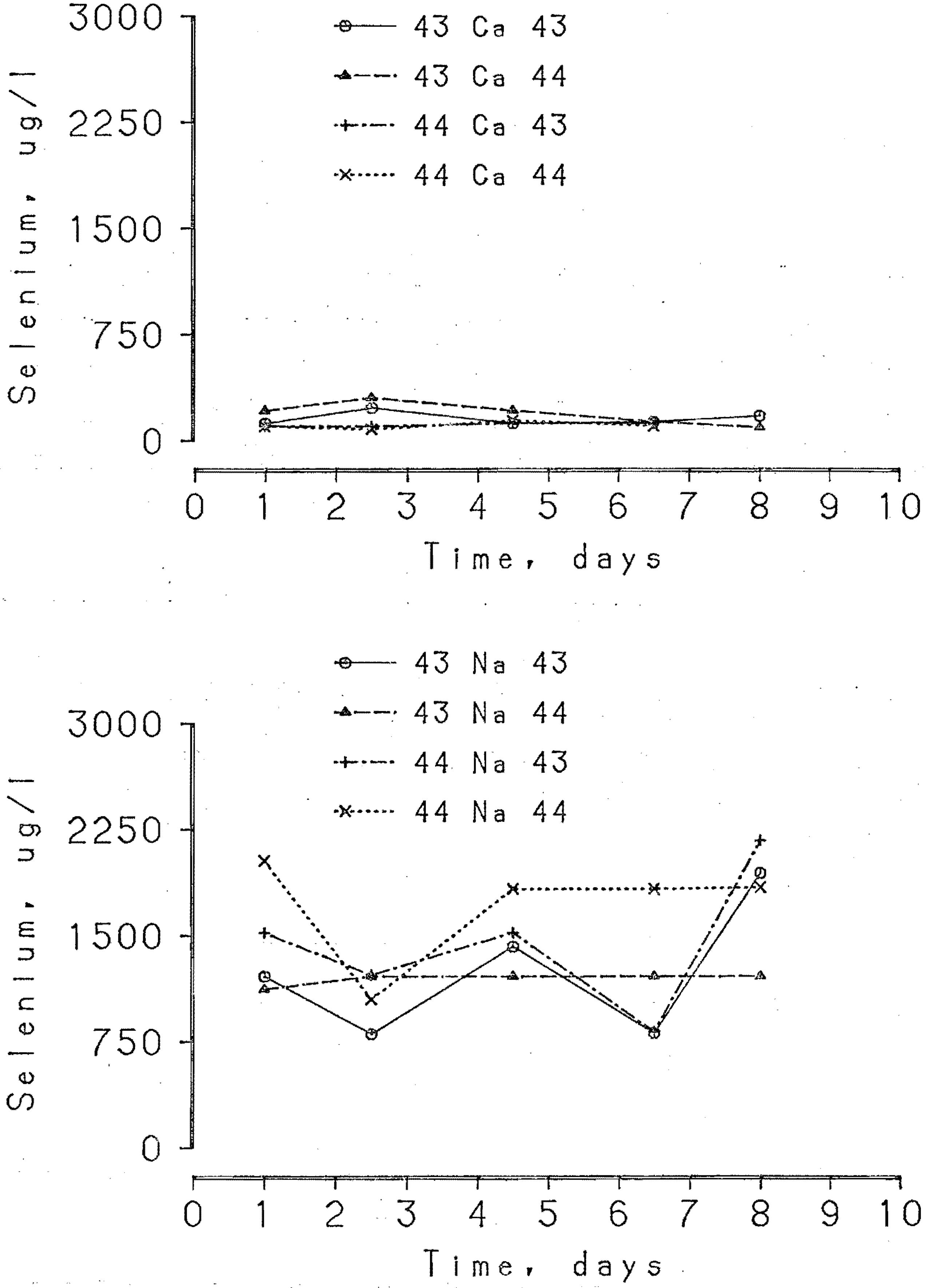
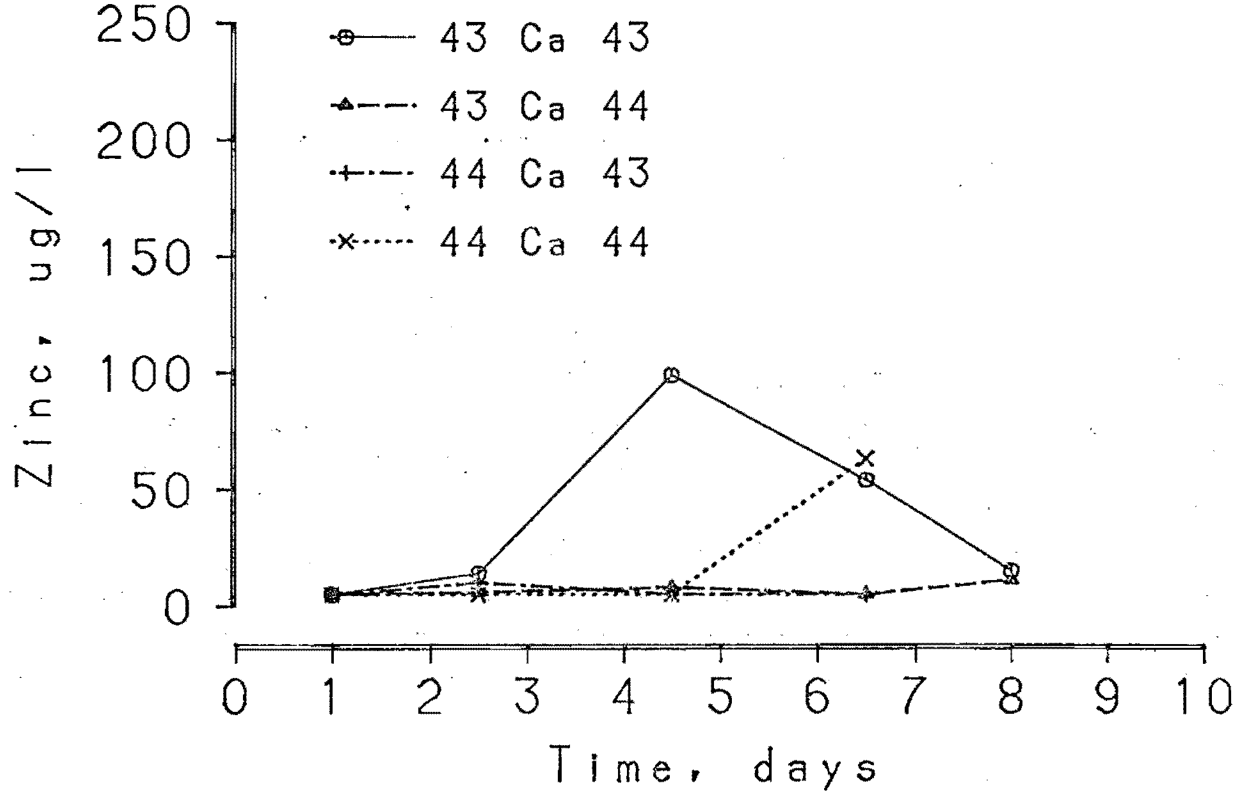


Figure 30. Selenium results from sequential columns. Upper: GW → overburden → calcium scrubber waste → overburden. Lower: GW → overburden → sodium scrubber waste → overburden.



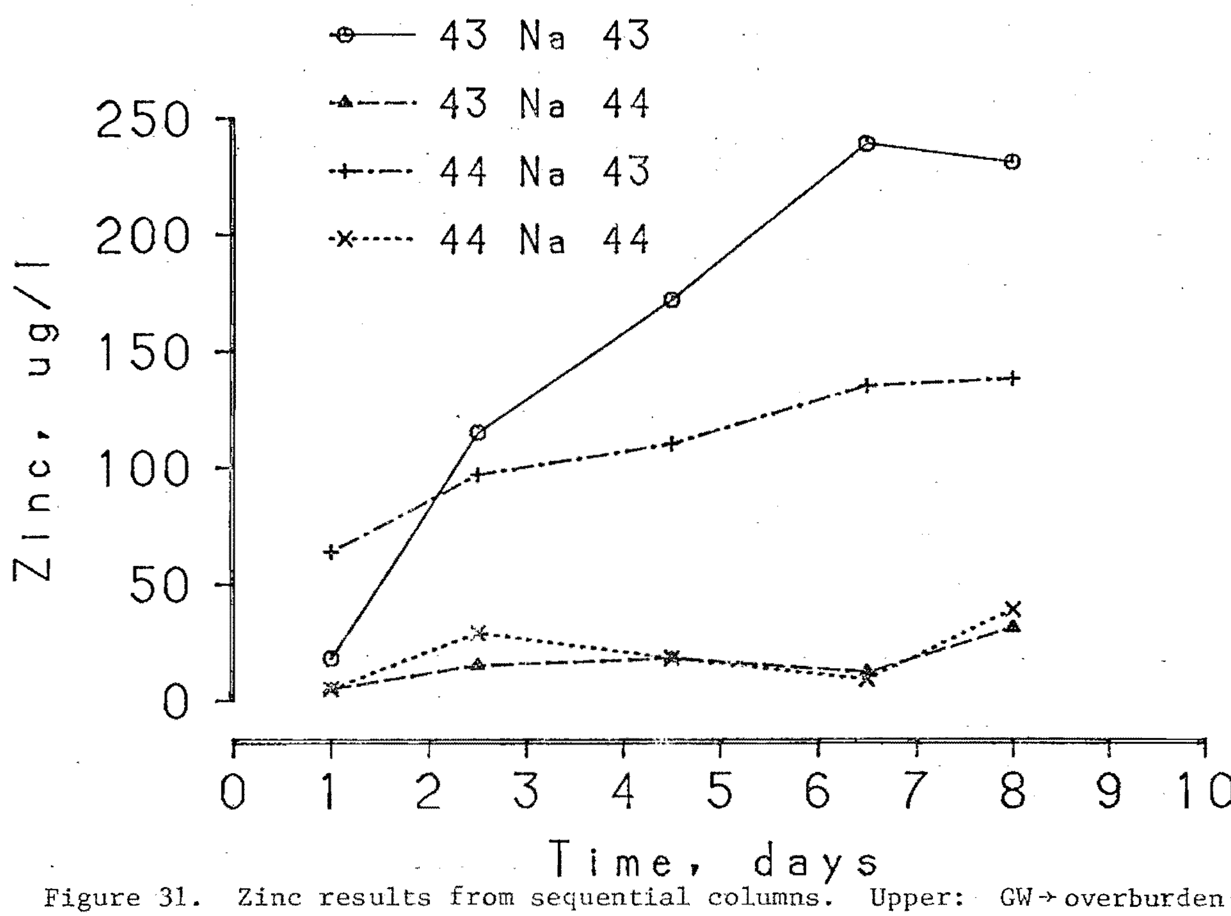


Figure 31. Zinc results from sequential columns. Upper: GW → overburden → calcium scrubber waste → overburden. Lower: GW → overburden → sodium scrubber waste → overburden.

Potassium and silver concentrations were determined on some selected samples (Appendix, Tables 47 and 48).

Batch Elutriation

Elutriate from the Topsoil (TS), Calcium Scrubber Waste (Ca SW), Sodium Scrubber Waste (Na SW), and Two Overburdens (OB 43 and OB 44) Using Doubly Deionized Water (DDW), Site Specific Groundwater (GW), and Acidified DDW

Groundwater, DDW, and acidified DDW were combined with five types of dry materials (Table 2) to evaluate differences in the water quality parameters for the 15 combinations of test waters and dry materials. The acidic DDW was used to simulate a potential acid rain condition. The chemical parameters evaluated are listed in Table 4. A summary of the results is shown in Table 44.

All elutriates obtained using groundwater exhibited much higher concentrations of calcium, magnesium, fluoride, total alkalinity, chloride, sulfate, total dissolved solids, and sodium as compared with DDW and acidic DDW elutriates. The higher concentrations appear, for the most part, to be resultant from high levels of these parameters initially present in the GW. The levels of Ca, Mg, and alkalinity are slightly lower in the elutriates derived using GW than in the GW itself. All scrubber waste elutriates show higher values in most parameters as compared with TS and OB 43 and 44. Of the two types of scrubber waste, Na SW elutriates have higher values for conductivity, total dissolved solids, total alkalinity, chloride, fluoride, sulfate, sodium, arsenic, boron, chromium, copper, lead, and selenium. As expected, the Ca SW elutriates are higher in calcium than the Na SW elutriates. The Ca SW elutriates

Table 44. Batch elutriation data.

Batch Elutriation

	pH	EC µmhos/cm at 25°C	TDS mg/l	Total Alkalinity as $CaCO_3$ mg/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate as N, mg/l	Nitrite as N, mg/l	Calcium mg/l	Magnesium mg/l	Sodium mg/l	Arsenic µg/l	Boron mg/l	Beryllium µg/l	Cadmium µg/l	Chromium µg/l	Copper µg/l	Lead µg/l	Mercury µg/l	Nickel µg/l	Selenium µg/l	Zinc µg/l
TS+DDW	7.9	322	228	62	9	0.9	60	2.9	0.1	36	6	<18	16	0.63	<14	<4	<10	8	4	0.6	<11	6	44
TS+GW	8.4	3,250	2,500	520	34	1.7	1020	4.7	0.2	66	23	733	15	0.86	<14	<4	<10	14	7	0.7	<11	20	45
TS+AW	8.3	349	248	74	9	0.9	68	1.0	0.1	41	4	<18	16	0.28	<14	<4	<10	<7	<1	0.4	<11	4	23
Ca+DDW	12.2	9,890	2,624	2210	27	4.0	411	1.8	1.5	762	19	204	17	8.04	<14	<4	93	18	7	0.7	<11	51	37
Ca+GW	12.3	13,800	4,410	2060	53	5.6	1360	2.0	2.0	752	49	914	17	7.46	<14	<4	113	18	<1	0.3	<11	60	48
Ca+AW	12.2	11,700	4,048	2260	32	5.4	1260	9.5	1.8	754	31	672	16	7.92	<14	<4	101	19	<1	0.8	<11	80	30
Na+DDW	10.2	19,500	17,260	2280	188	70	7340	7.5	4.5	8	4	4440	141	47.7	<14	<4	235	40	10	0.9	<11	131	30
Na+GW	9.9	21,500	20,300	3770	214	58	9690	7.5	4.5	16	16	5236	141	47.1	<14	<4	219	51	20	0.2	<11	130	25
Na+AW	10.1	20,700	18,110	2590	188	69	8940	8.5	4.0	9	6	4570	141	50.3	<14	<4	249	40	27	1.0	<11	212	27
43+DDW	8.2	407	284	46	10	0.6	97	1.4	<0.1	32	14	<18	13	0.61	<14	<4	<10	9	<1	0.4	<11	21	61
43+GW	8.4	3,470	2,470	474	35	1.5	1150	2.1	0.9	61	28	742	16	0.85	<14	<4	<10	11	<1	1.0	<11	12	51
43+AW	8.1	402	274	45	17	0.8	99	1.6	<0.1	33	15	<18	15	0.42	<14	<4	<10	<7	<1	<0.2	<11	12	44
44+DDW	8.0	934	610	42	5	0.7	271	5.9	0.1	61	23	77	16	1.42	<14	<4	<10	<7	<1	<0.2	<11	26	59
44+GW	8.4	3,670	2,940	513	31	1.7	1310	7.5	1.3	77	51	791	16	1.88	<14	<4	<10	8	<1	0.6	<11	11	53
44+AW	8.1	987	714	45	5	0.8	318	7.7	0.1	63	27	69	16	1.56	<14	<4	<10	14	<1	0.5	<11	17	44

TS = Topsoil
Ca = Calcium based scrubber waste
Na = Sodium based scrubber waste
43 = Overburden # 081043
44 = Overburden # 081044
DDW = Doubly-deionized water
GW = Groundwater
AW = Acidic doubly-deionized water (pH ≈ 4)

showed the highest pH values (12+). Na SW elutriate pH values were also high (≈ 10). Sodium, arsenic, boron, chromium, copper, lead, and selenium concentrations are higher in the Na SW elutriation media than any other solid material tested.

The levels of the chemical parameters in elutriates using acidic DDW did not show any particular trend when compared to DDW elutriates. The small amount of acid in the acidic DDW was insufficient to moderate the alkaline nature of the dry materials.

All of the trends described for the batch elutriation process were similar to the trends shown in the column leaching experiments.

CONCLUSIONS

Single Column Experiment Leachates

1. Most major cation and anion concentrations were very high in the initial leaching media and decreased with time.
2. The sodium based waste material produced major ion concentrations 50 to 100 percent higher than the calcium based scrubber wastes for both groundwater (GW) and doubly-deionized water (DDW) except for calcium concentrations.
3. Most of the major cation and anion concentrations were higher for DDW $\rightarrow$ coal than DDW $\rightarrow$ TS but were less than 10 percent of the Na SW leachate concentrations.
4. Leachates from the scrubber wastes had very alkaline pH's (Ca SW leachates, pH $\approx$ 12.5 Na SW leachate, pH $\approx$ 10).
5. GW leachates for coal and TS were not much different than the initial GW media.
6. Trace elements As, B, Cr, Cu, Se, and Zn were much higher (by an order of magnitude) in the Ca SW and Na SW leachates than leachates from the coal and TS.

Sequential Leaching

Initial Overburden Leachates

1. Overburdens (OB 43 and OB 44) leached with GW resulted in only slightly different concentrations in the leachate than the initial GW. Sulfate, nitrate and boron increased and zinc decreased.

2. For OB 43 and OB 44 leached with DDW → TS media, conductivity, total dissolved solids, alkalinity, chloride, fluoride, sulfate, nitrate, sodium, calcium, magnesium and boron concentrations increased. Although the concentrations increased, most were still less than the concentrations found in the GW → OB 43 and 44 leachates.

Scrubber Wastes Leachates

3. Leachates derived from the scrubber wastes had consistently high pH values (Ca SW leachates, pH ≈ 12.5 and Na SW leachate, pH ≈ 10.5).
4. Most major cation and anion concentrations followed trends similar to the single column leaching experiments where the initial concentrations were very high and decreased with time.
5. The Na SW material produced leachates with major ion concentrations 50 to 100 percent higher than the calcium based scrubber waste leachates for all the media types used except for the calcium concentration.
6. OB 44 derived leachate produced higher concentrations of the major ions than OB 43 derived leachates for both GW and DDW → TS.
7. Boron, copper and selenium concentrations in the scrubber wastes were higher coming from Na SW than Ca SW in most cases by a factor of 10.
8. Most major ions were slightly higher (approximately 10 percent) in the leachate from the Na SW and Ca SW leaching scheme than the major ion concentrations from the Na SW and Ca SW single column experiments.

Final Overburden Leachates

9. There was a slight drop in pH (up to 1.6 pH units) from the leachate through the overburdens.

10. The leachates derived from the Na SW were highly colored (red-brown) emerging from the overburdens.

11. Copper, nickel and zinc concentrations were always higher in the Na SW base leachates (generally by a factor of 10).

Batch Elutriation

1. Elutriates from Ca SW and Na SW had much higher concentrations of all the measured parameters (except calcium and magnesium in the Na SW elutriate) as compared with TS and OB elutriates.

2. Both Na SW and Ca SW elutriates produced pH values of 10 and 12, respectively, similar to the leaching experiments.

3. Na SW elutriates produced higher concentrations of sulfate, chloride, fluoride, alkalinity, nitrite and total dissolved solids as compared to Ca SW elutriates.

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APPENDIX

Table 45. Total organic carbon in the final tier of the groundwater sequential columns.

Sample	Total Organic Carbon mg/1
GW → OB 43 → Ca → OB 43, Day 2+3	100
GW → OB 43 → Ca → OB 44, Day 2+3	19
GW → OB 44 → Ca → OB 43, Day 2+3	31
GW → OB 44 → Ca → OB 44, Day 2+3	13
GW → OB 43 → Na → OB 43, Day 2+3	467
GW → OB 43 → Na → OB 44, Day 2+3	92
GW → OB 44 → Na → OB 43, Day 2+3	616
GW → OB 44 → Na → OB 44, Day 2+3	154

Table 46. Environmental Protection Agency interim primary drinking water standards.

Parameter	mg/l
Ba	1.0
Cd	0.01
Cr	0.05
Pb	0.05
Hg	0.002
Ag	0.05
As	0.05
CN	0.2
F	1.4-2.4 (depends on air temperature)
Se	0.01

Table 47. Potassium concentrations in selected samples.

Sample	Potassium, mg/l
GW, 9 Oct. 81	5
GW → OB 43, Day 1	11
GW → OB 43, Day 10+11	8
GW → OB 44, Day 1	17
GW → OB 44, Day 10+11	10
GW → OB 43 → Ca, Day 4+5	30
GW → OB 44 → Ca, Day 4+5	34
GW → OB 43 → Na, Day 4+5	190
GW → OB 44 → Na, Day 4+5	180
DDW → Topsoil, Day 1	2
DDW → Topsoil → OB 43, Day 1	7
DDW → Topsoil → OB 44, Day 1	8
DDW → Topsoil → OB 43 → Ca, Day 4+5	30
DDW → Topsoil → OB 44 → Ca, Day 4+5	30
DDW → Topsoil → OB 43 → Na, Day 4+5	200
DDW → Topsoil → OB 44 → Na, Day 4+5	180
DDW → Topsoil → OB 43 → Ca → OB 43, Day 4+5	35
DDW → Topsoil → OB 43 → Ca → OB 44, Day 4+5	40
DDW → Topsoil → OB 44 → Ca → OB 43, Day 4+5	40
DDW → Topsoil → OB 44 → Ca → OB 44, Day 4+5	50
DDW → Topsoil → OB 43 → Na → OB 43, Day 4+5	230
DDW → Topsoil → OB 43 → Na → OB 44, Day 4+5	250
DDW → Topsoil → OB 44 → Na → OB 43, Day 4+5	220
DDW → Topsoil → OB 44 → Na → OB 44, Day 4+5	240
GW → Topsoil, Day 1	6
GW → Coal, Day 1	20
GW → Ca, Day 1	140
GW → Na, Day 1	260
DDW → Topsoil, Day 1	2
DDW → Coal, Day 1	7
DDW → Ca, Day 1	70
DDW → Na, Day 1	260

Table 48. Silver concentrations in selected samples.

Sample	Silver, μg/l
DDW → Topsoil, Day 1	<4
DDW → Topsoil, Day 4+5	4
DDW → Coal, Day 1	<4
DDW → Coal, Day 4+5	<4
DDW → Ca, Day 1	21
DDW → Ca, Day 4+5	15
DDW → Na, Day 1	120
DDW → Na, Day 4+5	32
GW → Topsoil, Day 1	<4
GW → Topsoil, Day 4+5	9
GW → Coal, Day 1	18
GW → Coal, Day 4+5	<4
GW → Ca, Day 1	40
GW → Ca, Day 4+5	14
GW → Na, Day 1	94
GW → Na, Day 4+5	49