UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

ELEMENT LEVELS IN SELECTED SOILS AND PLANTS, WATTENMEER NATIONAL PARK, NORTH AND EAST FRISIAN ISLANDS, FEDERAL REPUBLIC OF GERMANY

by

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INTRODUCTION

A cooperative pilot project was initiated between the U.S. Geological Survey (USGS) and the Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) of the Federal Republic of Germany (FRG) in late 1987. Two coastal areas were selected to serve as analogues for studies involving processes of environmental degradation where industrial emissions and effluents containing trace elements were suspected: (1) Cape Romain National Wildlife Refuge, South Carolina, and (2) Wattenmeer National Park, FRG. The objectives of the pilot studies were to evaluate the feasibility of (1) distinguishing among natural and anthropogenic sources of trace metals; (2) determining the magnitude of trace-element enrichment from industrial sources; and (3) determining the trace metal levels in sediments and their potential uptake by marsh plants.

This report focuses on the cooperative work between the USGS and BGR at Wattenmeer National Park. Here we present the geochemistry of plants and soils collected at five barrier islands (Amrum, Baltrum, Langeoog, Norderney, and Wangerooge) in the North Sea (fig 1.). Subsequent reports will detail the studies at Cape Romain, South Carolina. We could find no information on the chemistry of plants and soils for these barrier islands, however, much information is available on the physical and chemical properties of water and sediments of the North Sea and the accumulation of metals by fish and wildlife. The information on water, sediments, fish, and wildlife is summarized in a recently published book edited by Salomons and others (1988).

Only two of the islands, Amrum and Norderney, permit motorized vehicles. On the other three islands, transportation is by bicycle or horse-drawn wagon. Each of the islands contain small villages and several permanent residents; however most of the land area of each island is undeveloped. Brick or cobblestone walking and bicycle paths are common throughout the islands. The islands support heavy seasonal day-use recreation.

METHODS

Field

Study Site Identification

The Frisian Islands are barrier islands built by the process of longshore drift. The islands are composed predominantly of fine sand and consist of parallel dune ridges rising to about 20 meters. The dunes are stabilized by vegetation, which typically consists of dune grasses on the windward side and crests of the dunes, and willow and associated shrubs in the depressions on the leeward side.

An unbalanced, nested, analysis-of-variance sampling design was used to assess geographical scales of elemental variability. Sampling sites were identified by positioning a barbell (fig. 2) with the long axis (5 km) parallel to the long axis of the island. The next shorter axis (1 km) of the barbell was rotated until sampling sites containing the desired plant species were identified. At one end of the 1-km axis, two sites were located for sampling approximately 100-m apart. At the other end of the 1-km axis, a single sampling site was located.

Samples of tidal marsh sediment and marsh grass were collected from one area of the continental coast (fig. 1) near the small village of Horum (the island of Wangerooge is directly off-shore). Three sampling sites were located along a 1500-m

transect. At each of the three sites, two samples of sediment and marsh grass were collected about 10-m apart.

Soil Sampling

Immature soil development (Entisol) was prevalent on the sand dunes examined at the five Frisian Islands. The soils consist of a very thin A-horizon (1-to-2 cm) and no visible B-horizon development. The A horizon is recognized by a slightly darker color, due to enrichment by organic matter, than the underlying parent material. Samples of the A-horizon were collected by first removing any plant debris from the surface and then scraping to the base of the A-horizon with a shovel. At each site, samples from two or three locations within a 2-m^2 area were composited. The samples were placed in 125 mL polyethylene bottles and shipped to the laboratories of the U.S. Geological Survey in Denver, Colorado.

Samples of tidal-marsh sediment were collected from the surface 3-4 cm of sediment using a shovel. A single sample consisted of a composite of sediment from 5 or 6 locations within a 2-m^2 area. The samples were placed in 125 mL polyethylene bottles and shipped to the laboratories of the U.S. Geological Survey in Denver, Colorado.

Vegetation Notes and Plant Sampling

The vegetation and phytosociology of the Frisian Islands has been extensively investigated in reports such as Klement (1953) and Gerhardt (1973). Because of the heavy use by both humans and grazing animals, many of the plant communities have been greatly altered. Within recent years, there has been strong government and public support of efforts to revegetate the dunes and to create less disturbed, more stable vegetation communities. Along the coast, where the reclaiming of agricultural lands from the sea continues, as it has for centuries, the role of salt marsh plant communities in the stabilization of sediments and in the creation of sustainable tidal/intertidal ecosystems is of great ecological interest (Beeftink, 1977; Westhoff, 1987).

Plant materials collected included the following: dune grass (*Ammophilia arenaria*), marsh grass (*Spartina anglica*), dune willow (*Salix repens*), sandorn (*Hippophae rhamnoides*), feather moss (*Hylocomium splendens*), and reindeer lichen (*Cladina rangiferina*).

Dune grass, marsh grass, and sandorn were all clipped using stainless steel shears and placed in 6x10-inch Hubco cloth bags. Dune grass samples consisted of a composite of material from 2-to-3 grass clumps located within about 1 m of each other. Samples were of the culms (stems) and leaves collected about 10 cm above the soil surface. Grass sampling sites were usually on or near dune crests. Flower heads were not common; when found they were removed so all samples would consist of the same plant materials.

Marsh grass samples consisted of the culms and leaves of individual plants collected from an area of about 1 m^2. The material was clipped about 10 cm above the sediment/water surface. Only very scattered flower heads were observed, so to maintain sample to sample homogeneity, they were not included in the sample.

Sandorn samples consisted of the terminal 10 cm of stems and leaves from a single shrub. Sites were few and always just to the lee of the first dune ridge beyond the beach.

Moss and lichen material was collected directly off the soil surface. As much as possible of the attendant detritus and adhering soil was removed in the field.

Each sample consisted of clumps from usually a very small area (<1 m^2). Samples were predominantly collected from near dune crests.

Willow samples consisted of the leaves from the branches of numerous neighboring shrubs. The material was a composite from shrubs growing within about a 4-to-5 m^2 area. Leaves were stripped from the terminal 8-10 cm of the branches while wearing leather gloves and represented the current year's growth. Willows were spindly with not much branching. Sites were usually in dune depressions. These areas were more moist and much more sheltered than the dune grass areas.

Laboratory Methods

Soil Sample Preparation and Analysis

Soil samples were dried under forced air at ambient temperature. The air-dry samples were disaggregated in a mechanical mortar and pestle and the minus 2-mm fraction saved. For all samples of dune sand, 100 percent of the mineral soil passed the 2-mm sieve--only coarse organic material (leaves and twigs) did not pass the sieve and was discarded. Samples of tidal-marsh sediment were generally fine sand and silt but contained some shells, which were discarded upon disaggregating and sieving through the 2-mm sieve. A split of the minus 2-mm material was ground to minus 80 mesh in a ceramic plate grinder and this material was used for chemical analysis.

Plant Sample Preparation and Analysis

Plant material was removed from the bags, placed in Teflon beakers, submerged and rinsed in deionized water, and drained. This process was repeated three times. Material was then placed on plastic colanders, rinsed briefly with deionized water, and allowed to drip drain. Colanders were then placed directly into ovens and the material was dried for 24 hrs. at about 40°C. Samples were ground in a Wiley mill to pass a 2-mm sieve.

Inductively Coupled Plasma

Samples were analyzed for 38 elements using inductively coupled plasma-atomic emission spectrometry (ICP-AES). Each soil sample (0.200g) and plant sample (0.100g of plant ash) was dissolved using a low-temperature (<150°C) digestion with concentrated hydrochloric, hydrofluoric, nitric, and perchloric acids (Crock and others, 1983). The acidic sample solution was taken to dryness and the residue was dissolved with 1 mL of aqua regia and then diluted to 10.0g with 1% v/v nitric acid. Reagent blanks, soil and plant reference materials (using both U.S. Geological Survey and National Institute for Standards and Technology reference materials), and sample replicates were all digested by the same procedure and analyzed at the same time as the samples. The elements determined and their determination limits are shown in Table 1. The elements Ag, Au, Be, Bi, Cd, Ho, Mo, Sn, Ta, and U were below detection in all soil samples; elements below detection in all plant samples were Ag, Au, Be, Bi, Ga, Ho, Mo, Nb, Sc, Sn, Ta, Th, U, and Yb. The relative standard deviation (RSD) for replicate determinations of the samples for most elements is five percent or less.

Continuous Flow Hydride Generation Atomic Absorption Spectroscopy

Arsenic and Se in soils and plants were determined by continuous-flow, hydride-generation atomic absorption spectroscopy (HGAAS) (Crock and Lichte, 1982; Crock and others, 1983; Sanzolone and Chao, 1987). A 0.25g soil sample was digested with nitric, perchloric, and hydrofluoric acids. After digestion, the sample was diluted to 50mL with 6N HCl. Arsenic and Se were determined independently using specifically designed continuous flow systems. In the procedure, the sample solution was reacted with sodium borohydride to generate the gaseous hydrides that were swept into the heated quartz furnace of an atomic absorption spectrometer. Arsenic and Se were determined using an aqueous standard calibration curve. Determination limits for As and Se are shown in Table 1. The RSD for the determination of both elements was about ten percent.

The determination of As and Se in vegetation by HGAAS also followed Crock and Lichte (1982). A 1.00g plant sample was digested with nitric and perchloric acids and 30 percent hydrogen peroxide. After digestion, the clear solution was diluted to 50mL with 6 N HCL. Arsenic and Se were then determined in the same fashion as for soil. An in-house standard alfalfa sample and a National Bureau of Standards standard Citrus Leaves were carried through the entire procedure. Unfortunately, both the standards and the majority of the samples were below the detection limit of 0.05 parts per million.

Miscellaneous Determinations

Total C in soils and total S in both soil and dry plant material were determined by combustion infrared photometry (Jackson and others, 1988).

Percent ash yield for plant samples was determined gravimetically following ashing at 450°C.

Mercury in soil and plants was determined using an automated, continuous-flow, cold-vapor, atomic absorption spectroscopic method (Kennedy and Crock, 1987). A 0.100g sample was digested with nitric acid and sodium dichromate in a closed Teflon bottle and then diluted to 12mL with deionized water. The solution was reacted with a sulfuric acid-hydroxylamine hydrochloride solution and stannous chloride solution in a continuous flow system. The gaseous Hg was separated in a phase separator and swept into a quartz cell of an atomic absorption spectrometer. Mercury was determined using an aqueous standard calibration curve.

Soil pH was determined by a 1:1 water extraction of the soil according to the method given in Crock and Severson (1980). A standard 1:1 (20g soil to 20g demineralized-deionized water) extraction was made, and the solution pH was measured using a standard pH meter calibrated with pH 7 and pH 10 buffer solutions.

Statistical Techniques

A five-level, unbalanced, nested, analysis-of-variance design was used to assess the landscape variability of element concentrations in plants and soils. This statistical design allows the partitioning of the total measured natural variation into distance-related components. The first of the five components (levels) is related to differences among the five islands sampled. The next three components are related to various sampling increments expressed as distances (5 km, 1 km, and 0.1 km) between sampling sites within each island. In addition, several samples were chosen at random and split into two parts; each part was analyzed independently. This duplicate analysis of samples is the fifth level of the design

and represents a non-distance related component that estimates all procedural errors.

A further precaution was taken to convert any systematic error, which might occur in either sampling or analysis, into random error. This was accomplished by analyzing all samples (original and duplicate samples) in a randomized sequence so that samples collected in the field to represent some geographic progression would not be analyzed in that same progression.

Statistical analyses require completely numeric data sets. Some elements were reported as being below the limit of determination (censored) of the analytical method (table 1). These elements are identified in tables 2, 5, 8, 11, 13, and 14 as having detection ratios of *m*:*n*, where *n* equals the total number of samples analyzed and *m* equals the number of uncensored samples. Where more that 20 percent of the determinations were below detection, summary statistics are presented but the element is omitted from any further interpretation. When some, but less than 20 percent, of the reported values were below determination the censored values were replaced with arbitrary values equal to 70 percent of their determination limit. The replacement values are justified because their small number neither alters the statistical tests nor affects the interpretation of the data. For the elements with censored distributions, the geometric means and deviations were estimated by the technique of Cohen (1959) for singly truncated distributions.

Data reported by the analyst for plant material on an ash-weight basis were converted to dry-weight equivalents and then transformed to logarithms prior to statistical analysis. Because ash-yield varies (Appendix tables A2, A3, A4, A6, and A7), the conversion from an ash-weight base to a dry-weight base produces variable lower limit of determination (LLD) values for elements with censoring. The mean and deviation estimation of Cohen (1959), however, can not handle variable LLD values. A single LLD was created using a procedure that adjusts the variable LLD values to a common value based on a procedure that produces the fewest overall changes in the data in order to make that adjustment.

DISCUSSION

Soil Chemistry and Aerial Trends

Summary statistics for elements in samples of A-horizon soils are presented in table 2. Several elements (Cd, Co, Cu, Nb, Nd, Ni, Sc, Se, Th, and Yb) were detected in less than 80 percent of the samples. Because of the low detection ratio for these elements, only summary statistics of the data are given and no further interpretation of the data will be made. The summary statistics provide an overview of the element concentration in soils from all five islands sampled. The observed range shows that, for more than half of the elements, the samples with lowest and highest element concentrations differ by a factor of four to eight. Several elements (Al, Ba, Co, K, Li, Na, Nb, Ni, P, Sc, Se, Sr, Th, and Yb) are relatively uniform from sample to sample, because they differ by a factor of three or less.

Analysis-of-variance data (table 3) show how the differences in geochemical variability are distributed among and within islands, and what proportion of the total variation is related to procedural errors. No elements exhibit excessive (>50 %) procedural error. However, Hg is approaching this arbitrary limit, and interpretation of the geochemical data for Hg as reflecting trends in natural geographic variability might actually represent procedural errors. For pH and 11 of the 23 elements, a large and/or statistically significant proportion of the natural

variation is between islands. This suggests that at least one of the five islands is geochemically different from the others for these elements.

For the remaining 11 elements, a large proportion of the natural geochemical variability exists within an island, and there are no statistically significant differences in geochemistry between islands. In other words, the geochemical variability within an island masks any geochemical differences between islands. Eight of the 11 elements showing large and/or significant variation between islands (table 3) are the same elements that show only small differences (factor of three or less) in their observed range (table 2). The additional three elements with large and/or significant variation between islands are total-C, Mg and Pb. Geometric means and deviations for all elements and pH are presented for each of the five islands in table 4. The 11 elements with large and/or significant variation, except for total-C (table 3), exhibit minimum mean concentrations at Amrum and Wangerooge Islands (table 4). Total-C is low at Norderney in addition to Amrum and Wangerooge. For other elements with large ranges in observed concentration (for example Mn in table 2), but no significant variation between islands (table 3), the range in geometric means between islands is not large enough to be statistically significant. This large range but lack of statistical significance between islands indicates that the variability of samples collected within an island is much greater than the variation observed between islands, and the most appropriate way to characterize the geochemistry of soils is to use the geometric mean and deviation presented in table 2 for all islands. Even though some geometric means in table 4 differ by a factor of two (Mn and Zn, for example), the means also exhibit large geometric deviations indicating high variability of the data used to construct the mean values.

Differences in soil geochemistry from one island to another show no clear patterns that indicate accumulations of trace elements from industrial emissions. As was mentioned earlier, motor vehicles are allowed on Amrum and Norderney, but are prohibited on the other four islands. The data for differences in average Pb content of the soils (table 4) from island to island shows Amrum and Norderney to be the lowest, and Langeoog to be the highest. This is not the pattern one would expect if significant Pb accumulations are related to motor vehicle emissions. The soils on Langeoog differ from those of the other islands in that they have the lowest pH's and highest total carbon contents (table 4). Associated with these extremes are the highest average values for As, Mn, Pb, V, Ti, and Zn (table 4). In addition, high values for Hg were measured in individual soil samples from Amrum, Langeoog, and Wangerooge (table A1), but the corresponding plant samples collected at these locations do not show similar elevated levels of Hg (tables A2, A3, and A4). Other trace elements of environmental concern, such as Cd, Cu, Mo, and Ni, were below detection levels in a large proportion of the samples, and, therefore, trends in the data could not be interpreted.

Plant Chemistry and Aerial Trends

Summary statistics for ash yield and the concentration of 24 elements in dune grass and 27 elements in both willow leaves and feather moss are presented in tables 5, 8, and 11. Several elements (Ce, Ti, and Y in willow and Nd in moss) were detected in less than 80 percent of the samples. Because of the low detection ratio for these elements, only the observed range of the data is given.

The summary statistics provide an overview of the element concentration in the plants collected from all five islands (for dune grass and willow) and from three of the five islands (for moss). The observed range in element concentrations for dune grass seldom exceeded a factor of five; however, a factor of 10 or greater

difference was observed for concentrations of Mn, Na, Sr, and Zn. The observed concentration range for Na differed by a factor of 26 and had a geometric deviation (GD) of 2.11. Dune grass has a shallow and extensive fibrous root system. The large differences in Na levels in dune grass reflect both the proximity of the ocean and the free movement of Na through the sandy soils and its uptake by the grass. Concentrations of Ba, Co, Li, Mn, and Na also exceeded a factor of ten in the willow samples. Interpretations of the element levels in moss samples is complicated by the extreme variability in the ash yield values. Even though the material was washed, soil contamination is apparent. Appendix table A4 lists the element data for individual samples and shows that one sample, A0311H, yielded nearly twice as much ash as any of the other samples. This sample also contains the highest concentrations of Al and Ti. Because of this apparent contamination, only limited interpretation of the moss data will be made in this report.

As with the soils data (table 3), the analysis of variance for element concentrations in dune grass and willow (tables 6 and 9, respectively) shows the distribution of the biogeochemical variability among and within islands, and the proportion of the total variation that is related to procedural error. In dune grass, only the analyses for Hg show excessive (>50%) procedural error. Results of analyses for Cr and total S were also high (30% and 38.7%, respectively) but not excessively high. Because of an insufficient quantity of sampled material, no duplicate laboratory analyses were conducted for willow samples and, therefore, no measure of procedural error exists (table 9). Procedural error for willow is included as part of the lowest (0-0.1km) ANOVA level.

Five elements in dune grass (table 6) and eight elements in willow (table 9) show a statistically significant proportion of the natural element concentration variation between islands. For Ca, Mg, Ni, P, and Sr in dune grass and Co, K, Mg, Na, P, S, Sr, and Zn in willow, there is evidence that at least one of the five islands is biogeochemically different. For elements that do not have large between-island variability (particularly in dune grass) (tables 6 and 9), the natural variability is variously segregated between the other three distance increments. There is a considerable proportion of the total natural variability that is found among samples collected on an individual island and that, for these elements, there is no statistically significant biogeochemical difference between islands. The biogeochemical variability for these elements within an island masks any biogeochemical differences between islands. Further, it is interesting to note that only Sr in dune grass and Co, Na, and Sr in willow are the same elements that show large (greater than about a factor of ten) differences in their observed concentration ranges (tables 5 and 8). This means that of the elements showing statistically significant differences between islands, only a very few showed truly large overall concentration differences.

Tables 7 and 10 present the geometric mean (GM) and GD values for element concentrations in dune grass and willow, respectively, among the five islands. Element concentrations in moss from three islands are presented in table 12. No discussion of the moss data is included because of the soil contamination discussed previously. There are no clear patterns in the data that relate differences in the biogeochemistry of the dune grass and willow from one island to another to accumulations of trace elements related to industrial emissions. In general, concentrations of such environmentally important elements as As, Cr, Cu, Ni, Pb, S, and V showed no west-to-east trends and were, in fact, very uniform and similar. As discussed above, concentrations of Hg in dune grass and willow between islands cannot be compared because of the very large procedural error associated with the analyses. The actual Hg concentrations, however, are similar to uncontaminated

material (Kabata-Pendias and Pendias, 1984). Cobalt, Mn, Ni, and Zn in willow are the only environmentally important elements that perhaps qualify as showing some west-to-east trends in concentration. These elements show (1) a factor of four or greater range in concentration (and a large geometric deviation), (2) their largest concentrations on the eastern-most island (usually highest on Amrum and lowest on either Norderney or Baltrum), and (3) except for Ni, show either very large or significant "between island" variability. The Pb concentrations are extremely uniform between islands and, like Pb in soils, show no elevated values on the two islands (Amrum and Norderney) that allow motorized vehicles.

Tidal-Marsh Soil and Plant Chemistry

The geochemistry of sediments and marsh grass collected from a tidal marsh off the continental coast near the small town of Horum is presented in tables 13 and 14. The concentrations in sediments for most elements are much greater than those measured in soils from the barrier islands (table 2). However, when compared to baseline data of fossil Rhine River sediments (table 1 in Beeftink and Rozema, 1988), the sediments we collected were comparable for Cr, Hg, Pb, and Sr and lower in concentration for Co, Cu, Ni, and Zn. Such comparisons for baseline element concentrations for marsh grass are not made because, as Beeftink and Rozema (1988, p.71) report, background element concentration values in salt-marsh plants are scarce. It is not meaningful to compare data from the different plant species collected on the islands with the data for the marsh grass samples.

Only Ca, Na, and Pb showed a statistically significant correlation between element levels in marsh grass and total element concentration in sediments (table 15). These significant correlations may be related to surface contamination of the plant material by sediment rather than reflecting plant uptake. Beeftink and Rozema (1988) and Beeftink and Nieuwenhuize (1986) have also explained that one reason for the scarce data for salt-marsh plants is that contaminated water and adhering clay particles make the establishment of soil-plant relationships difficult.

Correlations Between Elements in Plants and Soils

Geochemical data for paired samplings of plants and soils from all islands were combined into a single data file for computation of correlation coefficients between element concentrations in soils and plants. The correlation coefficients are presented in table 15. Few significant correlations were found between plant concentration and total element concentration in soil. It is generally accepted that total element concentration in soil is a poor indicator of the available fraction and plant uptake. Dune grass showed the most significant correlations of any plant species, but four of the seven coefficients were negative. Negative coefficients imply that as the concentration in one medium increases, it decreases in the other medium. These negative relationships are probably spurious, and several of the positive relations may be spurious also because there are no general trends from one plant species to the next. The only exceptions may be for Ca (significant positive correlations in three of the four plant species) and P (significant positive correlations in two of the four plant species). The elements showing significant positive correlations in at least one plant species are, except for Pb and Sr, major elements (Ca, K, Na, P, Pb, Sr, and Ti), and the positive relations may be related to element additions to the plant materials by contamination by small soil particles even though the plant preparation methods included washing.

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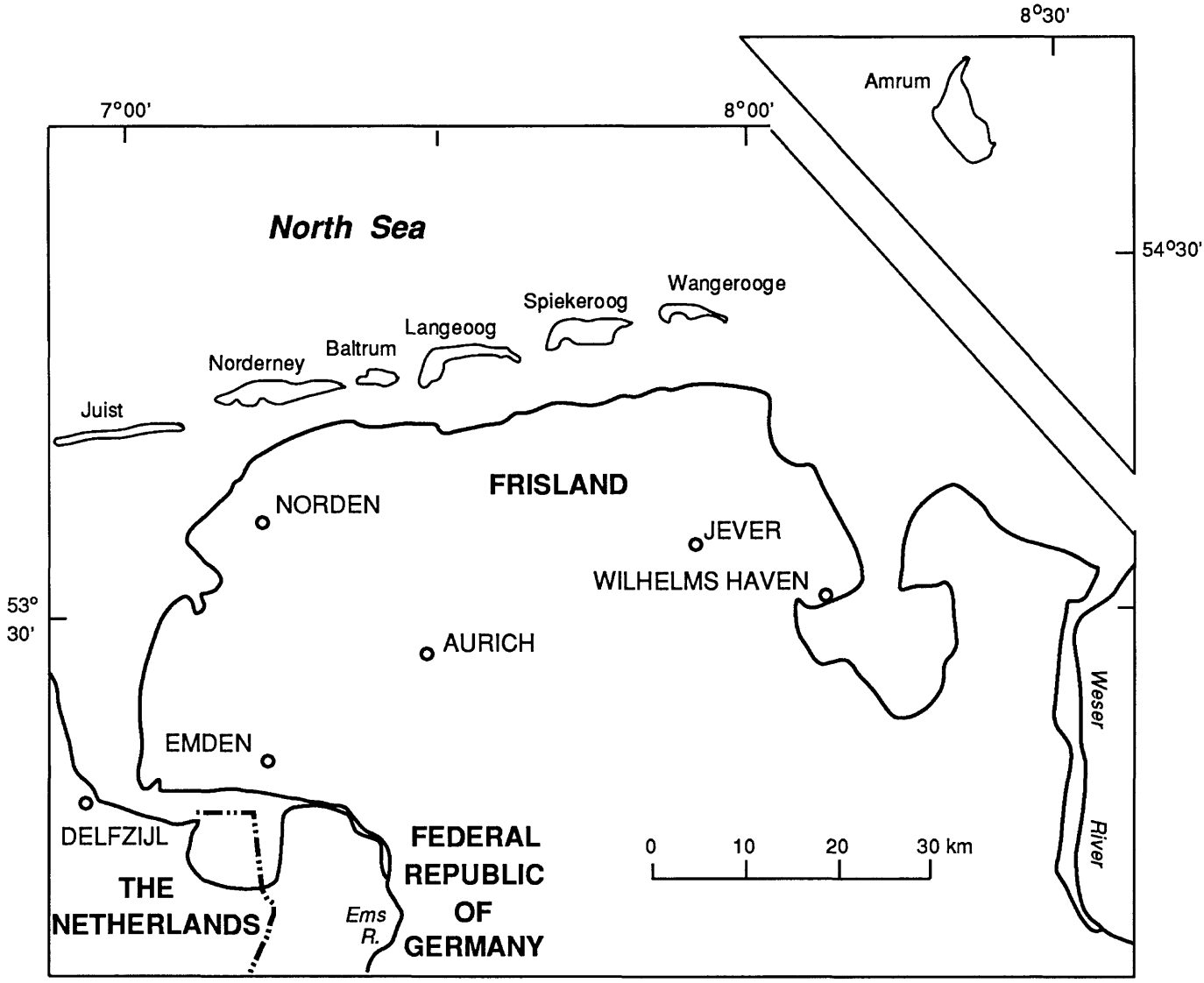
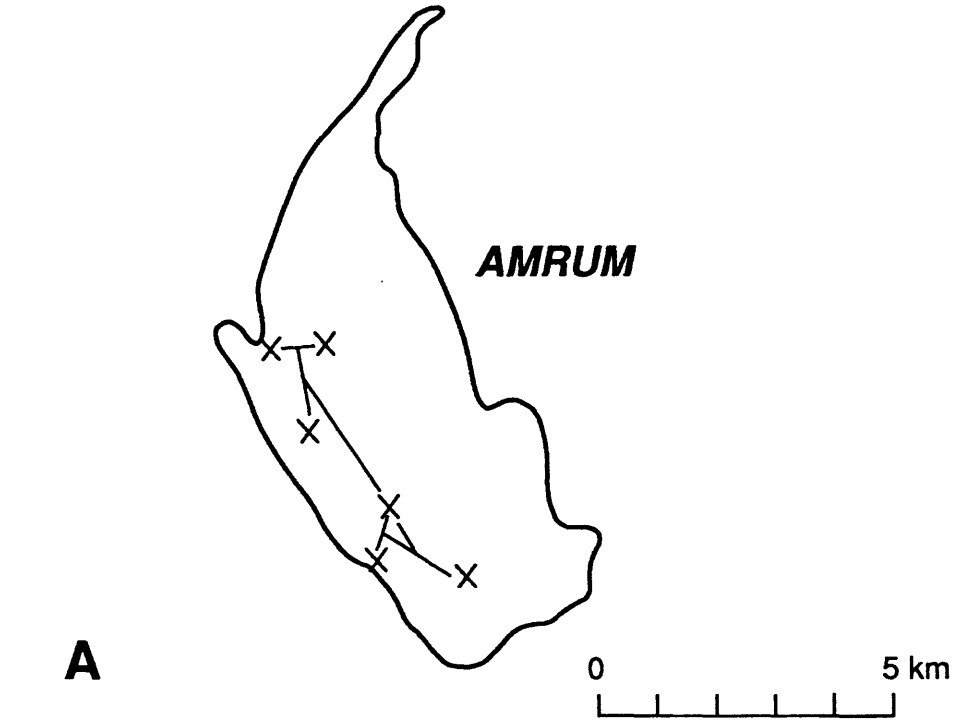


Figure 1. Location of the Frisian Islands study area.



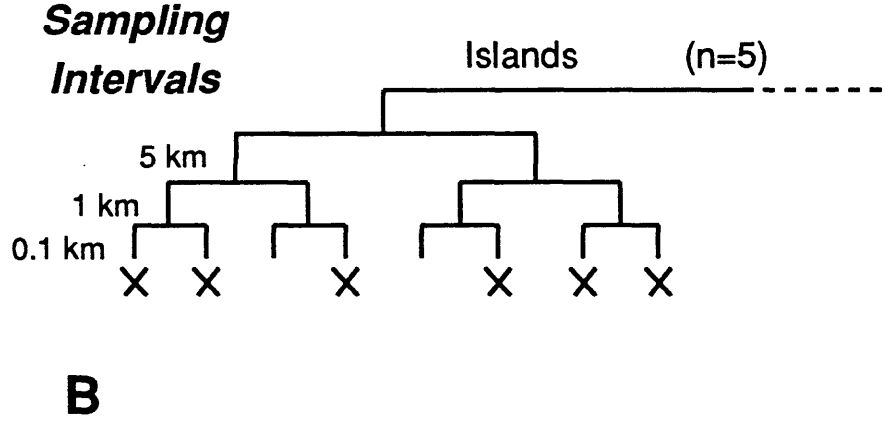


Figure 2. Diagram (A) and dendrogram (B) showing the unbalanced, nested, analysis-of-variance sampling design, illustrated for the island of Amrum.

Table 1.--Approximate limits of determination for pH and elements reported.

Analytical method	Medium	Determination limit	Variables
Continuous flow hydride generation	Soil	0.1 ppm	As, Se
	Plant	0.05 ppm	As, Se
Induction coupled plasma	Soil and Plant[1,2]	2.0 ppm	Ag, Cd, La, Li, Mo, Ni, Sc, Sr, V, Y, Zn
		0.05 %	Al, Ca, Fe, K, Mg, Na, P, Ti
		1.0 ppm	Ba, Be, Co, Cr, Cu, Yb
		4.0 ppm	Ce, Ga, Ho, Mn, Nb, Nd, Pb, Th,
		8.0 ppm	Au
		10 ppm	Bi
		20 ppm	Sn
		40 ppm	Ta
		100 ppm	U
Continuous flow cold vapor	Soil and Plant	0.02 ppm	Hg
Infrared detection	Soil	0.05 %	Total C, Total S
	Plant	0.05 %	Total S
Water slurry	Soil	0.1 units	pH

[1] Determined on plant ash.

[2] Sample mass for plants was one-half that for soils, so determination limits are twice those listed for soils.

Table 2. Summary statistics for the concentration of elements in surface soil samples from five Frisian Islands, Germany

[Be, Ga, and S were below detection in all samples; Detection ratio, number of samples in which the element was found in measurable concentrations relative to the number of samples analyzed]

Variable, unit of measure	Detection ratio	Geometric mean	Geometric deviation	Observed range
pH, std.[1]	37:37	5.3[2]	0.621[2]	4.0 - 6.6
Al, %	37:37	0.78	1.23	0.49 - 1.2
As, ppm	37:37	1.1	1.33	0.7 - 2.2
Ba, ppm	37:37	130	1.10	110 - 160
C-total, %	34:37	0.37	3.64	<0.05 - 0.62
Ca, %	37:37	0.12	1.52	0.05 - 0.32
Ce, ppm	37:37	11	1.56	5 - 40
Co, ppm	5:37	1.2	1.36	<1 - 2
Cr, ppm	37:37	6.8	1.65	3 - 20
Cu, ppm	25:37	1.3	1.83	<1 - 4
Fe, %	37:37	0.32	1.51	0.13 - 0.78
Hg, ppm	32:37	0.068	4.08	<0.02 - 3.4
K, %	37:37	0.50	1.14	0.36 - 0.66
La, ppm	37:37	5.7	1.53	3 - 20
Li, ppm	37:37	3.8	1.32	2 - 5
Mg, %	37:37	0.032	1.57	0.01 - 0.08
Mn, ppm	37:37	110	1.88	30 - 370
Na, %	37:37	0.21	1.29	0.12 - 0.34
Nb, ppm	5:37	4.5	1.20	<4 - 6
Nd, ppm	24:37	4.7	1.59	<4 - 16
Ni, ppm	1:37	-.-	-.-	<2 - 2
P, %	31:37	0.0072	1.34	<0.005 - 0.01
Pb, ppm	35:37	7.9	1.55	<4 - 18
Sc, ppm	2:37	-.-	-.-	<2 - 3
Se, ppm	12:37	0.1	1.00	<0.1 - 0.1
Sr, ppm	37:37	28	1.27	17 - 48
Th, ppm	3:37	-.-	-.-	<4 - 9
Ti, %	37:37	0.13	1.82	0.05 - 0.41
V, ppm	37:37	6.6	1.50	3 - 15
Y, ppm	31:37	3.1	1.63	<2 - 10
Yb, ppm	3:37	-.-	-.-	<1 - 1
Zn, ppm	37:37	7.0	1.94	3 - 19

[1] Measured in standard units

[2] Arithmetic mean and standard deviation

Table 3. Natural and analytical variation in the concentration of elements in surface soil samples from five Frisian Islands, Germany

Variable, unit of measure	Total log10 variance	Percentage of variance: Between Islands	1-5 km	0.1-1 km	0-0.1 km	Procedural error
pH, std.[1]	0.41480	25.8*	17.3	17.6	37.8*	1.5
Al, %	0.00912	49.4	24.3*	19.2*	5.5*	1.6
As, ppm	0.01967	0.0	39.6*	0.0	56.0*	4.4
Ba, ppm	0.00198	24.9*	9.1	29.0	26.8*	10.2
C-total, %	0.37791	12.0*	26.3	0.0	61.2	0.6
Ca, %	0.03589	31.0	30.2*	23.9*	12.3*	2.6
Ce, ppm	0.04670	0.0	45.5*	10.7	31.9*	11.9
Cr, ppm	0.05008	0.0	60.6*	3.9	16.1	19.4
Fe, %	0.04759	0.0	66.1*	21.9*	11.3*	0.7
Hg, ppm	0.51513	0.0	0.0	56.4	0.0	46.3
K, %	0.00378	47.1*	9.7	34.2*	4.4	4.6
La, ppm	0.04418	0.0	45.2*	13.1	27.0	14.7
Li, ppm	0.01803	74.2*	0.0	2.4	0.0	23.4
Mg, %	0.04456	33.4	39.3*	10.3	0.0	17.0
Mn, ppm	0.11211	0.0	71.4*	12.1	14.9*	1.6
Na, %	0.01425	68.1*	13.4	12.8*	3.0	2.7
P, %	0.02594	28.4*	6.6	22.2	38.6*	4.2
Pb, ppm	0.06526	24.3*	16.6*	0.0	57.2*	1.9
Sr, ppm	0.01195	54.7*	13.7	23.8*	5.0	2.8
Ti, %	0.10411	0.0	68.9*	11.5	18.5*	1.1
V, ppm	0.04320	0.0	66.6*	11.4	21.6*	0.4
Y, ppm	0.05731	0.0	68.1*	13.6	15.2*	3.1
Zn, ppm	0.05980	4.5	6.4	29.8	56.6*	2.7

[1] Variance is arithmetic.

* Statistically significant at the 0.05 probability level.

Table 4. Summary statistics for the concentration of elements in surface soil samples collected on individual Frisian Islands, Germany

[GM, geometric mean; GD, geometric deviation]

Variable, unit of measure	Amrum		Baltrum		Langeoog		Norderney		Wangerooge	
	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD
pH, std.[1]	5.2	0.313	5.4	0.714	4.6	0.692	5.9	0.338	5.4	0.342
Al, %	0.62	1.05	0.97	1.10	0.86	1.15	0.82	1.11	0.67	1.23
As, ppm	0.99	1.04	1.1	1.35	1.4	1.45	1.1	1.14	1.1	1.48
Ba, ppm	120	1.07	150	1.05	140	1.10	130	1.10	120	1.09
C-total, %	0.24	4.02	0.52	3.03	1.3	1.65	0.14	4.25	0.34	2.78
Ca, %	0.079	1.20	0.17	1.39	0.15	1.35	0.14	1.21	0.092	1.58
Ce, ppm	8.1	1.36	14	1.70	12	1.49	12	1.30	10	1.79
Cr, ppm	4.5	1.50	10	1.50	8.7	1.40	6.3	1.56	6.0	1.74
Fe, %	0.31	1.40	0.34	1.52	0.38	1.38	0.33	1.27	0.25	1.85
Hg, ppm	0.096	6.25	0.056	1.90	0.098	3.10	0.034	4.00	0.075	6.25
99 %	0.44	1.04	0.59	1.06	0.53	1.11	0.50	1.11	0.45	1.13
La, ppm	4.4	1.37	6.9	1.71	6.0	1.47	6.2	1.29	5.4	1.72
Li, ppm	2.4	1.24	4.7	1.12	-.-	-.-	4.6	1.12	3.7	1.14
Mg, %	0.018	1.30	0.046	1.30	0.038	1.20	0.039	1.27	0.026	1.69
Mn, ppm	90	1.79	120	1.85	160	1.55	130	1.55	86	2.49
Na, %	0.15	1.05	0.28	1.09	0.24	1.13	0.23	1.11	0.18	1.25
P, %	0.0048	1.46	0.0084	1.22	0.0090	1.21	0.0073	1.23	0.0067	1.38
Pb, ppm	6.3	1.43	8.9	1.33	14	1.32	6.2	1.36	6.9	1.50
Sr, ppm	21	1.08	36	1.14	31	1.16	30	1.12	24	1.24
Ti, %	0.13	1.82	0.12	1.87	0.17	1.67	0.10	1.51	0.12	2.24
V, ppm	6.0	1.50	7.5	1.42	8.3	1.35	6.5	1.22	5.2	1.80
Y, ppm	2.1	1.29	3.6	1.68	3.9	1.45	3.9	1.37	2.2	2.18
Zn, ppm	5.1	1.67	7.9	1.75	11	1.62	5.6	1.36	6.7	1.93

[1] Arithmetic mean and standard deviation.

Table 5. Summary statistics for the concentration of elements in dune grass samples from five Frisian Islands, Germany

[Cd, Ce, Nd, and Y were below detection in all samples; Detection ratio, number of samples in which the element was found in measurable concentrations relative to the number of samples analyzed]

Variable, unit of measure	Detection ratio	Geometric mean	Geometric deviation	Observed range
Ash, %	37:37	3.4	1.23	2.0 - 4.7
Al, %	37:37	0.0074	1.68	0.0020 - 0.017
As, ppm	25:37	0.061	1.39	<0.05 - 0.1
Ba, ppm	37:37	4.7	1.40	2.0 - 9.0
Ca, %	37:37	0.21	1.57	0.073 - 0.45
Co, ppm	34:34	0.12	1.36	0.05 - 0.18
Cr, ppm	37:37	0.47	1.35	0.20 - 0.71
Cu, ppm	37:37	3.0	1.19	1.5 - 4.0
Fe, %	37:37	0.0098	1.43	0.0045 - 0.018
Hg, ppm	37:37	0.038	1.27	0.030 - 0.10
K, %	37:37	0.73	1.54	0.25 - 1.6
La, ppm	27:34	0.20	1.29	<0.17 - 0.41
Li, ppm	35:37	0.35	1.59	<0.17 - 0.89
Mg, %	37:37	0.092	1.34	0.052 - 0.15
Mn, ppm	37:37	74	1.62	15 - 180
Na, %	37:37	0.12	2.11	0.017 - 0.45
Ni, ppm	34:37	1.1	1.67	<0.53 - 2.8
P, %	37:37	0.12	1.33	0.079 - 0.22
Pb, ppm	37:37	2.1	1.61	0.74 - 4.0
S-total, %	37:37	0.17	1.19	0.13 - 0.26
Se, ppm	11:37	0.045	1.22	<0.050 - 0.070
Sr, ppm	37:37	54	2.10	8.6 - 130
Ti, %	4:37	0.00037	1.71	<0.0007 - 0.0012
V, ppm	29:37	0.32	1.66	<0.19 - 0.68
Zn, ppm	37:37	18	1.59	6.3 - 106

Table 6. Natural and analytical variation in the concentration of elements in dune grass samples from five Frisian Islands, Germany

Variable, unit of measure	Total log10 variance	Percentage of variance: Between Islands	1-5 km	0.1-1 km	0-0.1 km	Procedural error
Ash, %	0.01017	0.0	50.7*	0.0	39.6*	9.7
Al, %	0.05388	0.0	59.7*	16.7*	13.8	9.8
Ba, ppm	0.02226	0.5	29.5*	32.0	30.5*	7.5
Ca, %	0.04696	53.8*	0.0	33.7*	7.2	5.3
Co, ppm	0.02349	13.0	2.8	0.0	66.2*	18.0
Cr, ppm	0.01861	1.1	55.9*	0.0	13.0	30.0
Cu, ppm	0.00676	0.6	17.3	47.3*	14.4	21.4
Fe, %	0.02880	0.0	63.2*	11.5	18.9*	6.4
Hg, ppm	0.01613	16.1*	0.0	0.0	0.0	83.9
K, %	0.04910	0.0	63.1*	21.1*	4.7	11.1
Li, ppm	0.04646	13.5	22.6*	10.9	25.9	27.1
Mg, %	0.01856	54.0*	14.8	15.4*	8.2	7.6
Mn, ppm	0.05067	0.0	0.0	52.1*	21.3	26.6
Na, %	0.13104	0.0	63.4*	14.3	21.5*	0.8
Ni, ppm	0.06649	38.3*	0.0	35.6*	0.0	26.1
P, %	0.02057	42.0*	0.0	37.7*	1.2	19.1
Pb, ppm	0.04567	5.2	51.2*	7.0	31.9*	4.7
S-total, %	0.00772	16.4	0.0	39.6*	5.3	38.7
Sr, ppm	0.11826	64.1*	9.1	3.9	20.1*	2.8
V, ppm	0.06010	0.0	65.8*	4.4	28.2*	1.6
Zn, ppm	0.05788	0.0	0.0	71.9*	19.4	8.7

* Statistically significant at the 0.05 probability level.

Table 7. Summary statistics for the concentration of elements in dune grass samples (dry-weight basis) collected from individual Frisian Islands, Germany.

[GM, geometric mean; GD, geometric deviation]

Variable, unit of measure	Amrum		Baltrum		Langeoog		Norderney		Wangerooge	
	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD
Ash, %	3.1	1.38	3.5	1.18	3.2	1.14	3.4	1.17	3.7	1.14
Al, %	0.0074	1.87	0.0047	1.87	0.010	1.52	0.011	1.33	0.0061	1.38
As, ppm	0.049	1.61	0.053	1.36	0.065	1.45	0.077	1.24	0.051	1.37
Ba, ppm	4.6	1.60	3.5	1.49	5.2	1.16	5.3	1.11	5.1	1.33
Ca, %	0.11	1.44	0.25	1.48	0.22	1.32	0.25	1.27	0.27	1.34
Co, ppm	0.075	1.35	0.11	1.56	0.14	1.11	0.13	1.08	0.12	1.38
Cr, ppm	0.42	1.34	0.36	1.50	0.51	1.43	0.59	1.10	0.48	1.24
Cu, ppm	3.0	1.13	2.5	1.35	3.1	1.18	2.9	1.14	3.2	1.15
Fe, %	0.0098	1.64	0.0071	1.40	0.012	1.45	0.012	1.21	0.0092	1.33
Hg, ppm	0.039	1.26	0.032	1.12	0.046	1.56	0.040	1.18	0.036	1.16
K, %	0.63	2.21	0.83	1.40	0.65	1.44	0.71	1.31	0.88	1.17
La, ppm	0.15	1.39	0.18	1.63	0.21	1.16	0.22	1.25	0.19	1.04
Li, ppm	0.48	1.70	0.30	1.79	0.39	1.22	0.40	1.47	0.24	1.30
Mg, %	0.062	1.19	0.099	1.33	0.081	1.13	0.12	1.18	0.10	1.18
Mn, ppm	93	1.63	59	2.45	59	1.26	64	1.47	96	1.35
Na, %	0.16	1.98	0.089	3.35	0.17	1.47	0.12	1.78	0.082	1.43
Ni, ppm	1.1	1.34	0.53	1.74	1.4	1.78	1.4	1.44	0.93	1.42
P, %	0.087	1.20	0.12	1.21	0.10	1.23	0.14	1.45	0.14	1.16
Pb, ppm	2.1	1.83	1.2	1.30	2.4	1.55	2.8	1.30	2.1	1.66
S-total, %	0.16	1.17	0.18	1.15	0.16	1.08	0.18	1.28	0.19	1.16
Se, ppm	0.053	1.11	-.-	-.-	0.044	1.40	-.-	-.-	-.-	-.-
Sr, ppm	17	1.83	73	1.73	69	1.47	62	1.37	80	1.52
Ti, %	0.0006	1.42	-.-	-.-	-.-	-.-	-.-	-.-	-.-	-.-
V, ppm	0.22	2.36	0.19	1.76	0.45	1.54	0.41	1.17	0.29	1.63
Zn, ppm	20	2.45	12	1.71	20	1.19	19	1.25	19	1.30

Table 8. Summary statistics for the concentration of elements in willow leaf samples (dry-weight basis) collected from five Frisian Islands, Germany

[Nd was below detection in all samples]; Detection ratio, number of samples in which the element was found in measurable concentrations relative to the number of samples analyzed]

Variable, unit of measure	Detection ratio	Geometric mean	Geometric deviation	Observed range
Ash, %	24:24	4.7	1.23	3.4 - 7.3
Al, %	24:24	0.0069	1.56	0.0028 - 0.016
As, ppm	11:24	0.49	1.39	<0.05 - 0.10
Ba, ppm	24:24	2.4	1.92	0.66 - 11
Ca, %	24:24	0.56	1.46	0.24 - 1.0
Cd, ppm	11:24	0.81	2.04	<0.9 - 3.7
Ce, ppm	1:24	-.-	-.-	<1.1 - 1.3
Co, ppm	24:24	2.4	1.92	0.9 - 12
Cr, ppm	24:24	0.44	1.29	0.29 - 0.67
Cu, ppm	24:24	5.9	1.39	3.8 - 13
Fe, %	24:24	0.011	1.26	0.0079 - 0.016
Hg, ppm	24:24	0.052	1.21	0.04 - 0.07
K, %	24:24	0.85	1.38	0.47 - 1.7
La, ppm	19:20	0.31	1.60	<0.17 - 1.4
Li, ppm	24:24	1.1	1.71	0.32 - 3.0
Mg, %	24:24	0.29	1.36	0.17 - 0.53
Mn, ppm	24:24	170	2.07	38 -510
Na, %	24:24	0.081	1.92	0.025 - 0.31
Ni, ppm	24:24	2.4	1.88	0.81 - 7.1
P, %	24:24	0.25	1.41	0.11 - 0.51
Pb, ppm	24:24	2.4	1.33	1.3 - 4.0
S-total, %	24:24	0.31	1.30	0.18 - 0.56
Se, ppm	7:24	0.032	1.90	<0.05 - 0.2
Sr, ppm	24:24	30	1.55	16 -110
Ti, %	1:24	-.-	-.-	<0.0007 - 0.0009
V, ppm	17:21	0.25	1.40	<0.19 - 0.47
Y, ppm	1:24	-.-	-.-	<0.53 - 0.61
Zn, ppm	24:24	240	1.50	130 -480

Table 9. Natural and analytical variation in the concentration elements in willow leaf samples from five Frisian Islands, Germany

Variable, unit of measure	Total log10 variance	Percentage of variance: Between Islands	1-5 km	0.1-1 km	0-0.1 km
Ash, %	0.01028	40.3*	0.2	0.0	51.1
Al, %	0.05137	20.0	36.4*	0.0	43.6
Ba, ppm	0.09428	17.5	18.8	0.0	63.7
Ca, %	0.04134	3.7	16.0	0.0	80.3
Co, ppm	0.10827	31.2*	0.0	36.8	32.0
Cr, ppm	0.01772	2.7	22.9	0.0	74.4
Cu, ppm	0.01809	23.5	0.0	56.0*	20.5
Fe, %	0.01245	0.0	23.9	0.0	76.1
Hg, ppm	0.00770	0.0	22.0	1.6	76.4
K, %	0.02548	53.5*	0.0	3.8	42.7
La, ppm	0.04416	17.5	0.0	2.4	80.1
Li, ppm	0.05690	13.0	18.4	8.1	60.5
Mg, %	0.02006	37.3*	23.5	0.0	39.2
Mn, ppm	0.12676	36.2	0.0	45.4*	18.4
Na, %	0.08575	20.6*	13.2	32.7	33.5
Ni, ppm	0.07878	8.5	17.2	48.5*	25.8
P, %	0.02530	62.2*	6.8	22.8*	8.2
Pb, ppm	0.02441	0.0	31.2*	0.0	68.8
S-total, %	0.01440	32.2*	6.4	0.0	61.4
Sr, ppm	0.06979	10.2*	0.0	0.0	89.8
Zn, ppm	0.03667	58.2*	7.3	0.0	39.5

* Statistically significant at the 0.05 probability level.

Table 10. Summary statistics for the concentration of elements in willow leaf samples (dry-weight basis) collected on individual Frisian Islands, Germany

[GM, geometric mean; GD, geometric deviation]

Variable, unit of measure	Amrum		Baltrum		Langeoog		Norderney		Wangerooge	
	GM	GD	GM	GD	GM	GD	GM	GD	GM	GD
Ash, ppm	4.2	1.22	5.6	1.13	4.3	1.09	4.1	1.22	6.0	1.18
Al, %	0.014	1.16	0.0050	1.40	0.0063	1.25	0.0079	1.61	0.0060	1.40
As, ppm	-.-	-.-	0.044	1.40	0.039	1.98	-.-	-.-	0.067	1.09
Ba, ppm	3.5	2.41	1.5	1.83	2.2	1.39	2.6	1.50	5.2	2.25
Ca, %	0.40	2.04	0.59	1.47	0.49	1.23	0.60	1.34	0.78	1.20
Cd, ppm	2.1	1.84	-.-	-.-	1.0	1.77	-.-	-.-	1.2	1.48
Co, ppm	6.9	1.60	2.0	1.82	2.2	1.43	1.9	2.04	2.1	1.49
Cr, ppm	0.37	1.13	0.40	1.16	0.41	1.31	0.50	1.40	0.54	1.15
Cu, ppm	5.3	1.34	5.9	1.28	5.8	1.24	5.5	1.15	8.9	1.40
Fe, %	0.012	1.31	0.011	1.21	0.010	1.22	0.012	1.34	0.013	1.20
Hg, ppm	0.059	1.18	0.048	1.17	0.049	1.27	0.054	1.22	0.057	1.11
K, %	0.57	1.12	1.1	1.22	0.89	1.14	0.68	1.34	1.1	1.45
La, ppm	0.53	2.28	0.33	1.52	0.25	1.62	0.28	1.21	0.28	1.05
Li, ppm	1.3	1.65	1.7	1.81	0.83	1.35	0.83	1.76	1.1	1.09
Mg, %	0.29	1.44	0.40	1.20	0.23	1.21	0.25	1.26	0.34	1.30
Mn, ppm	460	1.20	110	2.04	230	1.38	110	1.93	230	2.02
Na, %	0.056	1.62	0.082	1.61	0.060	1.58	0.080	2.15	0.22	1.34
Ni, ppm	5.6	1.23	1.7	2.21	2.8	1.45	2.2	1.85	1.8	1.20
P, %	0.14	1.19	0.31	1.16	0.27	1.12	0.22	1.30	0.36	1.36
Pb, ppm	2.3	1.23	2.0	1.24	2.4	1.30	2.8	1.47	2.6	1.09
S-total, %	0.27	1.27	0.37	1.23	0.29	1.14	0.26	1.28	0.40	1.34
Se, ppm	-.-	-.-	0.026	3.88	-.-	-.-	-.-	-.-	-.-	-.-
Sr, ppm	32	2.97	34	1.39	240	1.27	28	1.30	41	1.30
V, ppm	0.24	1.22	0.21	1.31	0.25	1.47	0.25	1.65	0.28	1.19
Zn, ppm	320	1.38	200	1.23	240	1.39	170	1.31	470	1.03

Table 11. Summary statistics for the concentration of elements in moss samples (dry-weight basis) from three Frisian Islands, Germany

[Cd was below detection in all samples; Detection ratio, number of samples in which the element was found in measurable concentrations relative to the number of samples analyzed]

Variable, unit of measure	Detection ratio	Geometric mean	Geometric deviation	Observed range
Ash, %	14:14	12	1.83	6.2 - 48
Al, %	14:14	0.14	1.65	0.056 - 0.38
As, ppm	14:14	0.17	1.73	0.07 - 0.6
Ba, ppm	14:14	28	1.57	13 - 72
Ca, %	14:14	0.31	1.29	0.22 - 0.59
Ce, ppm	11:14	2.3	2.61	<1.1 - 17
Co, ppm	10:10	0.44	1.65	0.26 - 1.1
Cr, ppm	14:14	2.4	1.48	1.2 - 4.8
Cu, ppm	14:14	7.5	1.41	4.7 - 14
Fe, %	14:14	0.082	1.73	0.030 - 0.30
Hg, ppm	14:14	0.12	1.18	0.08 - 0.14
K, %	14:14	0.26	1.19	0.18 - 0.34
La, ppm	14:14	1.5	2.07	0.56 - 8.7
Li, ppm	12:12	0.66	1.38	0.37 - 1.1
Mg, %	14:14	0.11	1.24	0.068 - 0.15
Mn, ppm	14:14	110	1.36	61 - 170
Na, %	14:14	0.061	1.29	0.045 - 0.10
Nd, ppm	3:14	-.-	-.-	<2.1 - 9.2
Ni, ppm	13:13	1.4	1.15	<1.1 - 1.7
P, %	14:14	0.076	1.31	0.043 - 0.10
Pb, ppm	14:14	13	1.30	8.0 - 20
S-total, %	14:14	0.13	1.21	0.08 - 0.16
Se, ppm	14:14	0.34	1.20	0.25 - 0.42
Sr, ppm	14:14	27	1.25	21 - 50
Ti, %	14:14	0.019	2.70	0.0025 - 0.15
V, ppm	14:14	3.2	1.35	1.7 - 6.3
Y, ppm	7:13	0.56	2.15	<0.53 - 2.4
Zn, ppm	14:14	36	1.81	13 - 89

Table 12. Summary statistics for the concentration of elements in moss samples (dry-weight basis) collected on individual Frisian Islands, Germany

[GM, geometric mean; GD, geometric deviation]

Variable, unit of measure	Amrum		Baltrum		Langeoog	
	GM	GD	GM	GD	GM	GD
Ash, ppm	21.8	2.45	9.0	1.39	12.0	1.65
Al, %	0.21	1.82	0.12	1.11	0.12	1.67
As, ppm	0.21	1.95	0.14	1.11	0.13	1.66
Ba, ppm	43	1.83	27	1.12	25	1.53
Ca, %	0.24	1.15	0.49	1.30	0.29	1.09
Ce, ppm	2.8	6.00	2.4	1.37	1.9	2.15
Co, ppm	-.-	-.-	0.63	2.27	0.39	1.42
Cr, ppm	3.0	1.60	2.6	1.08	2.0	1.34
Cu, ppm	8.1	1.56	11	1.51	6.3	1.12
Fe, %	0.14	2.05	0.069	1.03	0.072	1.55
Hg, ppm	0.11	1.32	0.13	1.06	0.11	1.15
K, %	0.27	1.32	0.20	1.19	0.27	1.04
La, ppm	2.3	3.47	1.5	1.29	1.2	1.83
Li, ppm	-.-	-.-	0.63	1.18	0.71	1.49
Mg, %	0.083	1.20	0.14	1.14	0.11	1.21
Mn, ppm	128	1.32	124	1.13	99	1.46
Na, %	0.075	1.44	0.050	1.18	0.060	1.28
Ni, ppm	1.5	1.04	1.5	1.04	1.2	1.10
P, %	0.054	1.37	0.087	1.16	0.079	1.22
Pb, ppm	13	1.08	16	1.40	11	1.30
S-total, %	0.11	1.42	0.15	1.05	0.13	1.08
Se, ppm	0.36	1.21	0.36	1.10	0.32	1.24
Sr, ppm	23	1.06	41	1.31	25	1.12
Ti, %	0.52	3.02	0.012	1.11	0.019	2.03
V, ppm	4.1	1.46	3.3	1.11	2.9	1.30
Y, ppm	-.-	-.-	0.57	1.00	0.60	1.98
Zn, ppm	18	1.40	59	1.45	37	1.85

Table 13. Summary statistics for the concentration of elements in sediment samples collected from a tidal marsh

[Detection ratio, number of samples in which the element was found in measurable concentrations relative to the number of samples analyzed]

Variable, unit of measure	Detection ratio	Geometric mean	Geometric deviation	Observed range
pH, std.	4:6[1]	7.9[2]	0.250[2]	7.6 - 8.2
Al, %	6:6	3.1	1.55	1.5 - 5.0
As, ppm	6:6	11	1.95	3.7 - 24
Ba, ppm	6:6	270	1.26	170 - 320
Be, ppm	3:6	0.98	1.86	<1 - 2
C-total, %	6:6	2.4	1.76	1.1 - 5.0
Ca, %	6:6	3.7	1.42	2.5 - 6.0
Ce, ppm	6:6	41	1.44	21 - 60
Co, ppm	6:6	6.4	1.64	3 - 11
Cr, ppm	6:6	51	1.78	19 - 95
Cu, ppm	6:6	8.2	1.94	4 - 18
Fe, %	6:6	1.6	1.88	0.57 - 3.2
Ga, ppm	5:6	7.0	1.70	<4 - 13
Hg, ppm	6:6	0.35	2.56	0.12 - 1.6
K, %	6:6	1.3	1.36	0.78 - 1.8
La, ppm	6:6	23	1.38	13 - 33
Li, ppm	6:6	24	1.82	10 - 49
Mg, %	6:6	0.59	1.92	0.2 - 1.2
Mn, ppm	6:6	640	2.11	240 - 1500
Na, %	6:6	1.3	1.60	0.58 - 2.1
Nb, ppm	1:6	-.-	-.-	<4 - 5
Nd, ppm	6:6	19	1.45	10 - 29
Ni, ppm	6:6	14	1.94	5 - 29
P, %	6:6	0.080	2.01	0.03 - 0.2
Pb, ppm	6:6	30	1.67	14 - 54
S-total, %	6:6	0.33	2.06	0.11 - 0.73
Sc, ppm	6:6	4.9	1.77	2 - 9
Se, ppm	6:6	0.27	2.02	0.1 - 0.7
Sr, ppm	6:6	180	1.31	140 - 270
Th, ppm	5:6	5.5	1.49	<4 - 9
Ti, %	6:6	0.20	1.41	0.11 - 0.29
V, ppm	6:6	47	1.87	18 - 96
Y, ppm	6:6	11	1.46	6 - 17
Yb, ppm	5:6	1.2	1.51	<1 - 2
Zn, ppm	6:6	69	1.95	25 - 150

[1] Insufficient sample for analysis.

[2] Arithmetic mean and standard deviation.

Table 14. Summary statistics for the concentration of elements in marsh grass samples (dry-weight basis) collected from a tidal marsh.

[Cd, Nd, and Se were below detection in all samples; Detection ratio, number of samples in which the element was found in measurable concentrations relative to the number of samples analyzed]

Variable, unit of measure	Detection ratio	Geometric mean	Geometric deviation	Observed range
Ash, %	6:6	12.7	1.09	11.4 - 14.3
Al, %	6:6	0.070	2.10	0.026 - 0.19
As, ppm	6:6	0.32	2.03	0.10 - 0.66
Ba, ppm	6:6	6.9	1.79	3.2 - 16
Ca, %	6:6	0.29	1.37	0.21 - 0.41
Ce, ppm	1:6	-.-	-.-	<1.1 - 1.6
Co, ppm	3:3	0.35	1.31	0.26 - 0.43
Cr, ppm	6:6	2.1	1.76	0.93 - 4.4
Cu, ppm	6:6	2.5	1.22	1.9 - 3.5
Fe, %	6:6	0.060	1.96	0.023 - 0.14
Hg, ppm	6:6	0.020	1.55	0.010 - 0.040
K, %	6:6	1.3	1.09	1.1 - 1.4
La, ppm	4:4	0.91	1.39	0.67 - 1.4
Li, ppm	6:6	1.3	1.54	0.70 - 2.4
Mg, %	6:6	0.31	1.23	0.22 - 0.40
Mn, ppm	6:6	120	1.19	91 - 150
Na, %	6:6	2.4	1.05	2.3 - 2.6
Ni, ppm	3:6	0.52	1.81	0.53 - 1.3
P, %	6:6	0.31	1.12	0.26 - 0.36
Pb, ppm	6:6	1.8	1.54	1.0 - 3.3
S-total, %	6:6	0.39	1.13	0.33 - 0.46
Sr, ppm	6:6	33	1.18	26 - 41
Ti, %	5:5	0.0038	1.67	0.0023 - 0.0086
V, ppm	6:6	1.7	2.13	0.58 - 4.4
Y, ppm	1:6	-.-	-.-	<0.54 - 0.57
Zn, ppm	6:6	26	1.03	25 - 27

Table 15. Correlation coeffients between elements in soils or sediments and four plants collected on the Frisian Islands, Germany

[Statistically significant at the 0.01 (**) or 0.05 (*) probability levels; -.-, Not determined]

Variable, unit of measure	Dune grass n=30	Willow n=24	Feather moss n=9	Marsh grass n=6
Al, %	-0.04	-0.41	-0.23	0.79
As, ppm	0.14	0.40	-0.04	0.59
Ba, ppm	-0.46**	-0.04	0.06	0.56
Ca, %	0.39*	0.53*	0.50	0.81*
Ce, ppm	-.-	-.-	0.17	-.-
Co, ppm	-0.10	-0.29	-0.33	-0.22
Cr, ppm	-0.04	0.04	0.04	0.74
Cu, ppm	0.13	0.13	-0.04	-0.10
Fe, %	0.20	0.07	0.40	0.76
Hg, ppm	0.21	-0.15	0.65	0.23
K, %	0.06	0.43	-0.41	0.69
La, ppm	0.33	0.12	0.13	0.25
Li, ppm	-0.39*	-0.05	-0.04	0.79
Mg, %	0.26	0.30	0.48	0.35
Mn, ppm	-0.42*	-0.14	-0.33	0.12
Na, %	0.04	-0.00	-0.43	0.81*
Ni, ppm	-0.36*	-0.21	0.00	0.76
P, %	0.13	0.62**	0.87**	0.62
Pb, ppm	-0.17	-0.13	-0.21	0.83*
S-total, %	-.-	-.-	-.-	0.68
Se, ppm	0.00	-0.24	0.30	-.-
Sr, ppm	0.47**	0.10	0.55	0.66
Ti, %	0.42*	-.-	0.63	0.73
V, ppm	0.19	0.10	0.52	0.80
Y, ppm	-.-	-.-	0.21	-.-
Zn, ppm	0.25	0.33	0.40	0.50

Table A1.--Listing of analytical data for samples of surface soils collected at five Frisian Islands, Germany.

[<, less than; ---, not determined]

Sample ID	Latitude	Longitude	pH, std.	Al, %	As, ppm	Ba, ppm	C-total, %	Ca, %	Ce, ppm	Co, ppm
					Amrum					
AMR 0311	543919	82001	5.4	0.64	1.0	130	0.12	0.10	12	<1
AMR 0312	543919	82001	5.6	0.66	1.0	130	0.12	0.09	11	<1
AMR 0321	543918	82006	5.2	0.60	0.9	120	0.14	0.07	6	<1
AMR 0331	543904	82020	4.9	0.66	1.0	130	1.0	0.09	8	<1
AMR 0341	543832	82044	5.4	0.58	1.0	110	<0.05	0.06	6	<1
AMR 0351	543831	82041	4.7	0.61	1.0	130	1.07	0.08	10	<1
AMR 0361	543805	82114	5.1	0.60	1.0	120	0.75	0.07	6	<1
					Baltrum					
BAL 0251	534354	72453	5.2	0.92	1.0	140	1.52	0.18	13	<1
BAL 0261	534353	72456	5.0	0.93	1.0	140	0.72	0.14	10	<1
BAL 0262	534353	72456	4.9	0.96	1.0	150	0.70	0.15	12	<1
BAL 0271	534305	72507	4.7	0.91	1.0	150	1.65	0.12	10	<1
BAL 0281	534338	72350	5.2	0.97	1.0	140	0.51	0.19	16	<1
BAL 0291	534338	72349	6.2	0.91	1.0	140	0.07	0.13	8	<1
BAL 0301	534356	72345	6.6	1.20	2.2	160	0.23	0.32	40	2
					Langeoog					
LAN 0191	534507	73522	4.0	0.93	2.0	140	2.08	0.16	18	1
LAN 0192	534507	73522	4.1	0.93	2.0	150	2.14	0.16	12	<1
LAN 0201	534506	73520	4.3	0.96	1.0	140	1.39	0.18	12	<1
LAN 0211	534508	73447	4.8	0.99	2.0	150	0.78	0.20	21	1
LAN 0221	534508	73202	4.9	0.68	1.0	120	2.06	0.09	7	<1
LAN 0231	534508	73201	4.3	0.75	1.0	120	0.89	0.11	8	<1
LAN 0241	534519	73210	6.0	0.84	1.0	130	0.68	0.19	10	<1
					Norderney					
NOR 0011	534310	71357	5.4	0.71	1.0	120	<0.05	0.10	8	<1
NOR 0021	534313	71353	6.2	0.72	1.4	110	0.19	0.13	16	<1
NOR 0031	534243	71348	5.6	0.88	1.0	140	<0.05	0.13	10	<1
NOR 0032	534243	71348	5.6	0.89	1.0	140	0.05	0.14	11	<1
NOR 0041	534305	71022	5.7	0.81	1.0	120	0.82	0.18	12	<1
NOR 0042	534305	71022	5.8	0.77	1.0	120	0.72	0.16	16	<1
NOR 0051	534304	71018	6.3	0.92	1.2	140	0.18	0.17	17	<1
NOR 0061	534240	71038	6.2	0.91	1.0	140	0.30	0.16	12	<1
					Wangerooge					
WAN 0131	534701	75658	5.6	0.59	0.9	120	0.38	0.07	10	<1
WAN 0141	534702	75654	5.4	0.67	0.9	130	0.74	0.08	5	<1
WAN 0151	534715	75611	5.2	0.49	0.7	110	0.10	0.05	5	<1
WAN 0152	534715	75611	5.3	0.53	0.9	110	0.10	0.06	7	<1
WAN 0161	534739	75223	5.4	0.80	2.0	140	0.32	0.14	20	1
WAN 0162	534739	75223	5.3	0.81	2.0	130	0.31	0.14	19	<1
WAN 0171	534739	75219	4.7	0.85	1.0	130	2.32	0.18	19	1
WAN 0181	534732	75144	5.9	0.68	1.0	120	0.30	0.09	11	<1

Table A1.--Listing of analytical data for samples of surface soils collected at five Friesian Islands, Germany (continued)

Sample ID	Cr, ppm	Cu, ppm	Fe, %	Hg, ppm	K, %	La, ppm	Li, ppm	Mg, %	Mn, ppm	Na, %
					Amrum					
AMR 0311	7	2	0.42	0.10	0.46	6	2	2	160	0.16
AMR 0312	7	3	0.40	0.08	0.46	6	3	2	160	0.16
AMR 0321	3	1	0.34	0.08	0.44	4	2	2	120	0.14
AMR 0331	6	2	0.43	3.40	0.46	4	3	2	120	0.16
AMR 0341	3	<1	0.20	---	0.41	3	3	1	36	0.15
AMR 0351	5	2	0.28	0.04	0.43	6	2	2	70	0.15
AMR 0361	3	2	0.20	0.12	0.45	3	2	2	51	0.15
					Baltrum					
BAL 0251	7	3	0.29	0.14	0.56	7	5	4	110	0.27
BAL 0261	9	<1	0.31	0.10	0.57	5	4	4	110	0.28
BAL 0262	13	<1	0.31	0.06	0.58	6	5	4	120	0.28
BAL 0271	6	<1	0.24	0.04	0.61	5	4	4	65	0.26
BAL 0281	12	1	0.43	0.06	0.56	9	5	5	180	0.27
BAL 0291	9	<1	0.23	0.02	0.57	4	5	4	61	0.28
BAL 0301	20	1	0.78	0.04	0.66	20	5	8	370	0.34
					Langeoog					
LAN 0191	9	2	0.44	0.06	0.56	10	4	4	180	0.26
LAN 0192	9	4	0.42	0.06	0.57	6	4	4	190	0.26
LAN 0201	10	1	0.48	0.08	0.57	6	4	4	200	0.26
LAN 0211	16	2	0.56	0.08	0.57	10	4	5	270	0.26
LAN 0221	6	3	0.23	0.08	0.45	4	4	3	77	0.19
LAN 0231	6	<1	0.26	0.04	0.47	4	4	3	98	0.22
LAN 0241	8	2	0.38	1.20	0.50	5	4	4	160	0.24
					Norderney					
NOR 0011	3	<1	0.22	0.08	0.45	5	5	3	60	0.21
NOR 0021	4	<1	0.27	---	0.43	8	4	3	93	0.21
NOR 0031	7	<1	0.28	0.14	0.55	4	4	3	89	0.26
NOR 0032	6	<1	0.30	0.16	0.56	6	5	4	120	0.26
NOR 0041	6	2	0.42	---	0.47	6	5	5	200	0.22
NOR 0042	12	2	0.40	0.02	0.46	7	4	5	190	0.21
NOR 0051	8	<1	0.43	---	0.52	9	5	5	190	0.25
NOR 0061	9	2	0.35	0.10	0.54	6	5	4	140	0.26
					Wangerooge					
WAN 0131	3	<1	0.15	---	0.43	5	4	2	39	0.16
WAN 0141	5	2	0.18	0.06	0.48	3	4	2	52	0.18
WAN 0151	3	1	0.13	0.06	0.36	3	3	1	30	0.12
WAN 0152	4	2	0.14	0.02	0.40	3	3	2	35	0.14
WAN 0161	9	2	0.46	0.92	0.50	10	4	4	190	0.21
WAN 0162	9	3	0.50	0.02	0.49	10	4	4	210	0.22
WAN 0171	12	1	0.56	0.08	0.50	9	4	5	290	0.22
WAN 0181	9	1	0.26	1.40	0.47	6	4	3	120	0.19

Table A1.--Listing of analytical data for samples of surface soils collected at five Friesian Islands, Germany (continued)

Sample ID	Nb, ppm	Nd, ppm	Ni, ppm	P, %	Pb, ppm	Sc, ppm	Se, ppm	Sr, ppm	Th, ppm	Ti, %
					Amrum					
AMR 0311	<4	5	<2	<0.01	6	<2	<0.1	22	<4	0.24
AMR 0312	<4	5	<2	<0.01	7	<2	<0.1	23	9	0.22
AMR 0321	<4	<4	<2	<0.01	5	<2	<0.1	20	<4	0.17
AMR 0331	<4	<4	<2	0.01	9	<2	0.1	23	<4	0.18
AMR 0341	<4	<4	<2	<0.01	<4	<2	<0.1	19	<4	0.05
AMR 0351	<4	6	<2	0.01	10	<2	0.1	21	<4	0.11
AMR 0361	<4	<4	<2	0.01	6	<2	<0.1	20	<4	0.07
					Baltrum					
BAL 0251	<4	7	<2	0.01	13	<2	0.1	35	<4	0.09
BAL 0261	<4	5	<2	0.01	9	<2	<0.1	34	<4	0.12
BAL 0262	<4	6	<2	0.01	9	<2	<0.1	35	<4	0.11
BAL 0271	<4	5	<2	0.01	9	<2	<0.1	33	<4	0.08
BAL 0281	<4	7	<2	0.01	9	<2	<0.1	35	<4	0.17
BAL 0291	<4	<4	<2	0.01	5	<2	<0.1	32	<4	0.06
BAL 0301	6	16	2	0.01	10	3	<0.1	48	5	0.41
					Langeoog					
LAN 0191	<4	6	<2	0.01	18	<2	0.1	33	<4	0.23
LAN 0192	<4	5	<2	0.01	17	<2	0.1	35	<4	0.20
LAN 0201	<4	5	<2	0.01	15	<2	0.1	34	<4	0.24
LAN 0211	5	9	<2	0.01	12	2	<0.1	36	<4	0.29
LAN 0221	<4	<4	<2	0.01	16	<2	0.1	24	<4	0.07
LAN 0231	<4	<4	<2	0.01	8	<2	0.1	27	<4	0.10
LAN 0241	<4	4	<2	0.01	13	<2	0.1	32	<4	0.17
					Norderney					
NOR 0011	<4	<4	<2		<4	<2	<0.1	24	<4	0.05
NOR 0021	<4	5	<2	0.01	8	<2	<0.1	26	<4	0.08
NOR 0031	<4	5	<2	0.01	5	<2	<0.1	31	<4	0.08
NOR 0032	<4	5	<2	0.01	5	<2	<0.1	33	<4	0.09
NOR 0041	<4	5	<2	0.01	8	<2	<0.1	30	<4	0.16
NOR 0042	<4	8	<2	0.01	8	<2	0.1	29	<4	0.16
NOR 0051	<4	5	<2	0.01	6	<2	<0.1	33	<4	0.15
NOR 0061	<4	5	<2	0.01	8	<2	<0.1	32	<4	0.11
					Wangerooge					
WAN 0131	<4	<4	<2	0.01	6	<2	<0.1	21	<4	0.05
WAN 0141	<4	<4	<2	0.01	7	<2	0.1	24	<4	0.07
WAN 0151	<4	<4	<2	<0.01	5	<2	<0.1	17	<4	0.05
WAN 0152	<4	<4	<2	<0.01	4	<2	<0.1	19	<4	0.06
WAN 0161	4	10	<2	0.01	7	<2	<0.1	28	<4	0.25
WAN 0162	4	10	<2	0.01	8	<2	<0.1	29	4	0.26
WAN 0171	4	7	<2	0.01	16	<2	0.1	32	<4	0.34
WAN 0181	<4	<4	<2	0.01	7	<2	<0.1	23	<4	0.15

Table A1.--Listing of analytical data for samples of surface soils collected at five Friesian Islands, Germany (continued)

Sample ID	V, ppm	Y, ppm	Yb, ppm	Zn, ppm
			Amrum	
AMR 0311	9	3	<1	5
AMR 0312	8	3	<1	4
AMR 0321	7	2	<1	4
AMR 0331	8	2	<1	14
AMR 0341	3	<2	<1	3
AMR 0351	6	2	<1	7
AMR 0361	4	<2	<1	4
			Baltrum	
BAL 0251	7	3	<1	15
BAL 0261	7	3	<1	6
BAL 0262	7	3	<1	6
BAL 0271	6	2	<1	6
BAL 0281	9	5	<1	8
BAL 0291	5	3	<1	4
BAL 0301	15	10	1	19
			Langeoog	
LAN 0191	10	4	<1	15
LAN 0192	10	5	<1	14
LAN 0201	10	5	<1	11
LAN 0211	11	6	1	10
LAN 0221	5	2	<1	12
LAN 0231	6	3	<1	4
LAN 0241	8	4	<1	17
			Norderney	
NOR 0011	5	2	<1	5
NOR 0021	5	4	<1	4
NOR 0031	6	3	<1	4
NOR 0032	6	4	<1	5
NOR 0041	8	5	<1	8
NOR 0042	8	5	<1	8
NOR 0051	8	5	<1	8
NOR 0061	7	4	<1	5
			Wangerooge	
WAN 0131	3	<2	<1	3
WAN 0141	4	<2	<1	6
WAN 0151	3	<2	<1	4
WAN 0152	3	<2	<1	4
WAN 0161	9	5	<1	15
WAN 0162	9	5	<1	17
WAN 0171	13	5	1	11
WAN 0181	5	3	<1	5

Table A2.--Listing of analytical data for samples of dune grass collected at five Frisian Islands, Germany.

[Results reported on a dry-weight basis; <, less than; ---, not determined]

Sample ID	Latitude	Longitude	Ash, %	Al, %	As, ppm	Ba, ppm	Ca, %	Cd, ppm	Ce, ppm	Co, ppm
					Amrum					
A0311A	543919	82001	1.99	0.0133	0.09	2.4	0.084	<0.9	<1	0.080
A0312A	543919	82001	1.96	0.0118	0.09	2.4	0.082	<0.9	<1	0.11
A0321A	543918	82006	2.62	0.0165	0.08	3.4	0.073	<0.9	<1	0.079
A0331A	543904	82020	2.47	0.0091	0.05	4.0	0.20	<0.9	<1	0.049
A0341A	543832	82044	4.74	0.0052	<0.05	9.0	0.10	<0.9	<1	---
A0351A	543831	82041	3.39	0.0044	<0.05	5.1	0.13	<0.9	<1	0.10
A0361A	543805	82114	3.98	0.0036	<0.05	6.4	0.092	<0.9	<1	---
					Baltrum					
B0251A	534354	72453	2.91	0.0041	<0.05	4.9	0.35	<0.9	<1	0.058
B0261A	534354	72956	4.15	0.0029	0.07	4.6	0.22	<0.9	<1	0.17
B0262A	534354	72456	4.13	0.0033	<0.05	3.6	0.22	<0.9	<1	0.12
B0271A	534347	72508	4.09	0.0020	<0.05	2.3	0.24	<0.9	<1	---
B0281A	534338	72351	3.17	0.0076	0.07	5.1	0.20	<0.9	<1	0.13
B0291A	534338	72350	3.00	0.0051	<0.05	3.3	0.16	<0.9	<1	0.15
B0301A	534357	72346	4.06	0.0114	0.07	2.0	0.45	<0.9	<1	0.081
					Langeoog					
L0191A	534507	73522	3.50	0.0077	0.07	5.3	0.19	<0.9	<1	0.14
L0192A	534507	73522	3.61	0.0079	0.07	6.1	0.20	<0.9	<1	0.18
L0201A	534506	73520	3.77	0.0053	<0.05	6.0	0.25	<0.9	<1	0.15
L0211A	534509	73447	2.86	0.0112	0.10	4.6	0.29	<0.9	<1	0.14
L0221A	534508	73203	2.78	0.0114	0.08	4.2	0.18	<0.9	<1	0.11
L0231A	534509	73202	3.33	0.0147	<0.05	5.3	0.14	<0.9	<1	0.13
L0241A	534520	73210	2.85	0.0160	0.08	6.0	0.29	<0.9	<1	0.14
					Norderney					
N0011A	534311	71358	2.72	0.0106	0.07	4.9	0.27	<0.9	<1	0.14
N0021A	534313	71353	3.68	0.0088	0.06	5.5	0.29	<0.9	<1	0.11
N0031A	534244	71349	4.35	0.0065	0.07	6.1	0.30	<0.9	<1	0.13
N0041A	534306	71023	3.39	0.0112	0.10	5.4	0.28	<0.9	<1	0.14
N0042A	534305	71023	3.42	0.0106	0.08	6.2	0.28	<0.9	<1	0.14
N0051A	534304	71019	3.09	0.0133	0.10	5.3	0.19	<0.9	<1	0.12
N0061A	534240	71038	3.26	0.0143	0.07	4.6	0.18	<0.9	<1	0.13
N0232A	534244	71349	4.28	0.0060	0.06	5.6	0.29	<0.9	<1	0.13
					Wangerooge					
W0131A	534702	75659	3.11	0.0081	0.06	4.4	0.31	<0.9	<1	0.12
W0141A	534703	75655	4.02	0.0036	0.06	3.0	0.35	<0.9	<1	0.080
W0151A	534716	75611	3.61	0.0087	0.08	6.1	0.40	<0.9	<1	0.14
W0152A	534758	75611	3.62	0.0087	0.08	5.8	0.36	<0.9	<1	0.14
W0161A	534739	75224	4.37	0.0061	<0.05	6.1	0.21	<0.9	<1	0.17
W0162A	534739	75224	4.38	0.0070	0.06	6.6	0.21	<0.9	<1	0.18
W0171A	534738	75220	3.86	0.0050	<0.05	6.2	0.21	<0.9	<1	0.077
W0181A	534733	75144	3.16	0.0066	<0.05	5.7	0.21	<0.9	<1	0.13

Table A2.--Listing of analytical data for samples of dune grass collected at five Friesian Islands, Germany (continued).

Sample ID	Cr, ppm	Cu, ppm	Fe, %	Hg, ppm	K, %	La, ppm	Li, ppm	Mg, %	Mn, ppm	Na, %
					Amrum					
A0311A	0.56	2.8	0.015	0.04	0.28	<0.16	0.70	0.056	56	0.24
A0312A	0.53	2.7	0.014	0.04	0.27	<0.16	0.71	0.055	55	0.24
A0321A	0.52	2.9	0.018	0.05	0.25	0.24	0.89	0.052	73	0.45
A0331A	0.54	3.2	0.012	0.04	0.47	0.17	0.52	0.077	62	0.14
A0341A	0.38	3.3	0.0076	0.03	1.6	---	0.19	0.071	180	0.061
A0351A	0.27	2.5	0.0058	0.03	0.95	<0.16	0.41	0.071	156	0.17
A0361A	0.36	3.5	0.0060	0.05	1.3	<0.16	0.48	0.052	92	0.10
					Baltrum					
B0251A	0.23	3.5	0.0058	0.03	0.73	0.17	<0.16	0.11	140	0.027
B0261A	0.46	3.1	0.0062	0.04	1.2	0.17	0.25	0.15	87	0.017
B0262A	0.33	3.2	0.0062	0.03	0.78	<0.16	<0.16	0.15	87	0.017
B0271A	0.20	2.6	0.0045	0.03	1.3	<0.16	0.41	0.12	38	0.077
B0281A	0.41	2.1	0.0095	0.03	0.82	0.22	0.35	0.079	41	0.15
B0291A	0.42	2.6	0.0075	0.03	0.63	<0.16	0.72	0.069	147	0.33
B0301A	0.57	1.5	0.011	0.03	0.57	0.41	0.24	0.085	15	0.27
					Langeoog					
L0191A	0.35	3.0	0.0088	0.10	0.70	0.18	0.35	0.081	77	0.22
L0192A	0.58	3.1	0.0090	0.04	0.76	0.22	0.36	0.083	79	0.23
L0201A	0.30	3.1	0.0064	0.03	0.94	0.19	0.45	0.094	68	0.13
L0211A	0.54	4.0	0.013	0.03	0.54	0.23	0.29	0.074	40	0.18
L0221A	0.61	3.1	0.014	0.04	0.70	0.19	0.47	0.092	64	0.14
L0231A	0.67	3.0	0.015	0.05	0.87	0.23	0.37	0.080	50	0.11
L0241A	0.71	2.4	0.017	0.05	0.34	0.26	0.46	0.068	60	0.31
					Norderney					
N0011A	0.54	2.7	0.011	0.05	0.57	0.19	0.35	0.12	63	0.070
N0021A	0.59	3.0	0.010	0.04	0.74	0.18	0.40	0.13	55	0.051
N0031A	0.52	3.4	0.0091	0.04	1.1	0.30	0.52	0.12	96	0.17
N0041A	0.58	3.1	0.012	0.04	0.71	0.27	0.31	0.14	95	0.14
N0042A	0.62	3.2	0.012	0.04	0.72	0.27	0.31	0.14	92	0.14
N0051A	0.62	2.3	0.015	0.03	0.71	0.19	0.25	0.10	34	0.17
N0061A	0.68	2.7	0.014	0.04	0.52	0.20	0.72	0.088	65	0.23
N0232A	0.51	3.4	0.0090	0.04	1.1	0.26	0.51	0.12	94	0.17
					Wangerooge					
W0131A	0.59	3.7	0.012	0.04	0.72	0.19	0.25	0.084	100	0.062
W0141A	0.44	2.7	0.0060	0.03	0.88	0.20	0.20	0.088	64	0.052
W0151A	0.61	2.9	0.013	0.04	0.76	0.18	0.40	0.13	83	0.086
W0152A	0.51	2.8	0.012	0.04	0.76	0.22	0.36	0.13	83	0.083
W0161A	0.44	3.3	0.0092	0.04	1.1	---	0.22	0.096	96	0.12
W0162A	0.48	3.3	0.0092	0.04	1.1	---	0.22	0.096	92	0.12
W0171A	0.35	3.9	0.0073	0.03	1.0	0.19	0.19	0.11	162	0.069
W0181A	0.47	3.0	0.010	0.04	0.88	0.19	0.22	0.11	92	0.13

Table A2.--Listing of analytical data for samples of dune grass collected at five Friesian Islands, Germany (continued).

Sample ID	Nd, ppm	Ni, ppm	P, %	Pb, ppm	Se, ppm	S-total, %	Sr, ppm	Ti, %	V, ppm	Zn,ppm
					Amrum					
A0311A	<2	0.84	0.070	3.0	0.05	0.14	8.8	0.0008	0.52	11
A0312A	<2	0.82	0.071	2.9	0.06	0.14	8.6	0.0008	0.47	11
A0321A	<2	0.92	0.092	3.7	0.06	0.16	11	0.0010	0.52	9.7
A0331A	<2	0.84	0.12	4.0	0.05	0.16	21	<0.0007	0.40	106
A0341A	<2	1.1	0.085	1.3	<0.05	0.14	13	<0.0007	<0.19	15
A0351A	<2	1.8	0.075	1.4	<0.05	0.14	47	<0.0007	<0.19	27
A0361A	<2	1.1	0.092	1.0	<0.05	0.21	19	<0.0007	<0.19	13
					Baltrum					
B0251A	<2	<0.5	0.12	1.2	<0.05	0.22	116	<0.0007	<0.19	26
B0261A	<2	0.62	0.15	1.3	<0.05	0.19	62	<0.0007	<0.19	16
B0262A	<2	0.66	0.15	1.2	<0.05	0.20	66	<0.0007	<0.19	17
B0271A	<2	<0.5	0.11	0.74	<0.05	0.16	90	<0.0007	<0.19	16
B0281A	<2	0.76	0.11	1.5	<0.05	0.16	63	<0.0007	0.32	6.3
B0291A	<2	1.2	0.14	1.2	<0.05	0.18	29	<0.0007	0.21	10
B0301A	<2	<0.5	0.085	1.5	0.05	0.15	130	0.0012	0.41	7.3
					Langeoog					
L0191A	<2	1.9	0.12	1.6	<0.05	0.16	77	<0.0007	0.32	23
L0192A	<2	2.0	0.12	1.6	<0.05	0.16	79	<0.0007	0.29	24
L0201A	<2	2.3	0.13	1.2	<0.05	0.15	124	<0.0007	0.23	19
L0211A	<2	0.69	0.089	2.8	0.07	0.17	66	<0.0007	0.60	20
L0221A	<2	1.3	0.086	3.3	<0.05	0.18	44	<0.0007	0.50	25
L0231A	<2	2.7	0.077	2.9	<0.05	0.15	47	<0.0007	0.57	18
L0241A	<2	0.74	0.12	3.7	0.06	0.15	83	<0.0007	0.68	15
					Norderney					
N0011A	<2	1.1	0.12	3.3	0.05	0.14	79	<0.0007	0.46	16
N0021A	<2	1.2	0.16	2.1	<0.05	0.21	96	<0.0007	0.33	17
N0031A	<2	1.8	0.22	2.3	<0.05	0.25	61	<0.0007	0.35	14
N0041A	<2	2.6	0.15	3.3	<0.05	0.19	64	<0.0007	0.41	26
N0042A	<2	2.8	0.15	3.4	<0.05	0.19	65	<0.0007	0.44	25
N0051A	<2	0.96	0.11	4.0	<0.05	0.13	40	<0.0007	0.49	22
N0061A	<2	1.3	0.10	2.3	<0.05	0.19	49	<0.0007	0.42	20
N0232A	<2	1.8	0.22	2.4	<0.05	0.26	60	<0.0007	0.34	15
					Wangerooge					
W0131A	<2	0.62	0.15	3.4	<0.05	0.15	93	<0.0007	0.47	21
W0141A	<2	0.64	0.17	1.1	<0.05	0.18	121	<0.0007	<0.19	15
W0151A	<2	0.90	0.14	4.0	0.06	0.19	123	<0.0007	0.51	20
W0152A	<2	0.87	0.14	3.6	0.05	0.19	119	<0.0007	0.51	20
W0161A	<2	1.1	0.12	1.7	<0.05	0.20	70	<0.0007	0.26	14
W0162A	<2	1.2	0.11	1.8	<0.05	0.20	70	<0.0007	0.31	14
W0171A	<2	1.5	0.12	1.5	0.06	0.23	66	<0.0007	0.19	28
W0181A	<2	1.0	0.15	2.4	<0.05	0.17	41	<0.0007	0.35	17

Table A3.--Listing of analytical data for samples of willow leaves collected at five Frisian Islands, Germany.

[Results reported on a dry-weight basis; <, less than; ---, not determined]

Sample ID	Latitude	Longitude	Ash, %	Al, %	As, ppm	Ba, ppm	Ca, %	Cd, ppm	Ce, ppm	Co, ppm
					Amrum					
A0341W	543832	82044	3.38	0.014	<0.05	1.8	0.24	2.3	<1.0	6.1
A0351W	543831	82041	5.06	0.012	<0.05	9.6	0.91	3.7	1.3	11
A0361W	543805	82114	4.26	0.016	0.06	2.5	0.30	1.1	<1.0	4.7
					Baltrum					
B0251W	534354	72453	5.65	0.0051	<0.05	1.0	0.45	<0.9	<1.0	1.9
B0261W	534354	72456	4.74	0.0028	<0.05	0.66	0.45	<0.9	<1.0	1.3
B0271W	534347	72508	5.94	0.0042	0.06	1.2	0.47	<0.9	<1.0	1.6
B0281W	534338	72351	5.72	0.0069	<0.05	3.9	0.92	0.97	<1.0	5.7
B0291W	534338	72350	5.04	0.0066	<0.05	1.8	0.47	<0.9	<1.0	2.4
B0301W	534357	72346	6.77	0.0061	0.07	1.8	1.0	<0.9	<1.0	1.0
					Langeoog					
L0191W	534507	73522	4.63	0.0093	0.10	2.4	0.56	1.1	<1.0	3.1
L0201W	534507	73520	3.90	0.0055	<0.05	1.4	0.47	<0.9	<1.0	1.1
L0211W	534509	73447	4.18	0.0063	<0.05	3.2	0.63	0.92	<1.0	2.2
L0221W	534508	73203	4.43	0.0058	<0.05	1.8	0.34	1.1	<1.0	2.3
L0231W	534509	73202	4.00	0.0068	0.07	1.9	0.48	<0.9	<1.0	2.5
L0241W	534520	73210	4.81	0.0048	<0.05	3.2	0.53	2.6	<1.0	2.5
					Norderney					
N0011W	534311	71358	3.61	0.011	0.06	2.7	0.61	<0.9	<1.0	0.90
N0021W	534313	71353	4.14	0.0037	<0.05	1.2	0.66	<0.9	<1.0	0.95
N0031W	534244	71349	3.54	0.0053	<0.05	2.7	0.50	<0.9	<1.0	4.2
N0041W	534305	71023	6.05	0.011	0.06	3.9	0.97	0.91	<1.0	2.4
N0051W	534304	71019	3.98	0.012	0.06	3.3	0.56	<0.9	<1.0	1.2
N0061W	534240	71038	3.76	0.0090	<0.05	2.4	0.41	<0.9	<1.0	4.1
					Wangerooge					
W0161W	534739	75224	5.30	0.0085	0.07	5.3	0.64	1.7	<1.0	2.0
W0171W	534740	75220	5.71	0.0057	0.06	11	0.91	1.4	<1.0	1.5
W0181W	534733	75144	7.27	0.0044	0.07	2.3	0.80	<0.9	<1.0	3.3

Table A3.--Listing of analytical data for samples of willow leaves collected at five Friesian Islands, Germany (continu

Sample ID	Cr, ppm	Cu, ppm	Fe, %	Hg, ppm	K, %	La, ppm	Li, ppm	Mg, %	Mn, ppm	Na, %
					Amrum					
A0341W	0.34	4.1	0.010	0.05	0.57	0.37	2.1	0.21	372	0.032
A0351W	0.35	5.0	0.010	0.06	0.51	1.4	1.4	0.44	506	0.066
A0361W	0.43	7.2	0.016	0.07	0.64	0.30	0.77	0.27	511	0.081
					Baltrum					
B0251W	0.34	6.8	0.0090	0.06	1.0	---	2.3	0.53	79	0.062
B0261W	0.33	5.2	0.0085	0.04	0.90	0.24	2.2	0.44	119	0.047
B0271W	0.42	7.1	0.013	0.04	1.4	0.24	3.0	0.42	71	0.11
B0281W	0.46	6.3	0.013	0.05	1.0	0.57	2.7	0.35	297	0.074
B0291W	0.40	7.1	0.011	0.05	0.91	0.35	0.91	0.32	186	0.071
B0301W	0.47	3.8	0.013	0.05	1.4	---	0.74	0.37	41	0.18
					Langeoog					
L0191W	0.65	6.5	0.015	0.07	0.79	0.28	1.3	0.30	222	0.056
L0201W	0.35	4.7	0.0086	0.05	0.82	<0.17	0.74	0.24	254	0.025
L0211W	0.29	4.2	0.010	0.04	0.88	0.50	0.63	0.17	167	0.071
L0221W	0.40	7.1	0.0097	0.06	0.97	0.22	0.80	0.19	248	0.075
L0231W	0.44	6.0	0.010	0.04	0.80	0.24	1.2	0.24	152	0.064
L0241W	0.38	6.7	0.0087	0.04	1.1	---	0.63	0.23	370	0.096
					Norderney					
N0011W	0.65	5.4	0.015	0.05	0.47	0.25	0.32	0.19	72	0.072
N0021W	0.29	4.6	0.0079	0.05	0.87	0.21	0.66	0.19	38	0.050
N0031W	0.39	5.7	0.0088	0.04	0.67	0.32	1.2	0.23	181	0.039
N0041W	0.67	5.9	0.015	0.07	1.0	0.36	1.7	0.28	182	0.31
N0051W	0.64	6.4	0.016	0.06	0.56	0.28	0.76	0.33	119	0.12
N0061W	0.53	4.5	0.013	0.06	0.60	0.26	0.98	0.29	196	0.053
					Wangerooge					
W0161W	0.58	8.0	0.014	0.06	1.1	0.27	1.2	0.39	472	0.17
W0171W	0.46	6.9	0.011	0.06	0.80	0.29	1.0	0.39	211	0.22
W0181W	0.58	13	0.015	0.05	1.7	---	1.2	0.25	116	0.31

Table A3.--Listing of analytical data for samples of willow leaves collected at five Friesian Islands, Germany (continu

Sample ID	Nd, ppm	Ni, ppm	P, %	Pb, ppm	Se, ppm	S-total, %	Sr, ppm	Ti, %	V, ppm	Y, ppm	Zn ppm
						Amrum					
A0341W	<2	5.4	0.11	2.0	0.05	0.21	17	<0.0007	0.24	<0.5	223
A0351W	<2	7.1	0.16	2.2	<0.05	0.34	111	<0.0007	0.20	0.61	435
A0361W	<2	4.7	0.14	2.9	0.05	0.27	17	0.0009	0.30	<0.5	328
						Baltrum					
B0251W	<2	1.0	0.32	1.8	<0.05	0.35	32	<0.0007	---	<0.5	175
B0261W	<2	0.81	0.29	1.3	<0.05	0.29	36	<0.0007	<0.19	<0.5	161
B0271W	<2	1.1	0.39	2.1	<0.05	0.38	35	<0.0007	---	<0.5	267
B0281W	<2	4.7	0.31	2.0	<0.05	0.37	57	<0.0007	---	<0.5	252
B0291W	<2	4.6	0.28	2.3	0.20	0.32	21	<0.0007	0.20	<0.5	181
B0301W	<2	1.3	0.26	2.4	0.06	0.53	31	<0.0007	0.27	<0.5	190
						Langeoog					
L0191W	<2	2.2	0.26	3.7	0.05	0.34	25	<0.0007	0.46	<0.5	208
L0201W	<2	3.6	0.30	1.7	<0.05	0.28	20	<0.0007	<0.19	<0.5	183
L0211W	<2	2.1	0.22	2.7	<0.05	0.33	29	<0.0007	0.29	<0.5	255
L0221W	<2	2.3	0.29	2.4	<0.05	0.27	16	<0.0007	0.22	<0.5	328
L0231W	<2	5.2	0.26	2.2	<0.05	0.24	30	<0.0007	0.28	<0.5	168
L0241W	<2	2.2	0.29	2.1	<0.05	0.29	26	<0.0007	0.19	<0.5	380
						Norderney					
N0011W	<2	1.1	0.17	3.6	0.05	0.18	29	<0.0007	0.47	<0.5	148
N0021W	<2	1.6	0.17	1.6	<0.05	0.28	23	<0.0007	<0.19	<0.5	145
N0031W	<2	5.7	0.20	1.9	<0.05	0.23	34	<0.0007	<0.19	<0.5	127
N0041W	<2	2.7	0.31	3.8	0.05	0.38	42	<0.0007	0.30	<0.5	266
N0051W	<2	1.3	0.29	4.0	<0.05	0.24	25	<0.0007	0.36	<0.5	199
N0061W	<2	3.0	0.20	2.8	<0.05	0.26	21	<0.0007	0.23	<0.5	154
						Wangerooge					
W0161W	<2	1.6	0.31	2.9	<0.05	0.33	44	<0.0007	0.32	<0.5	482
W0171W	<2	1.5	0.29	2.6	<0.05	0.35	51	<0.0007	0.23	<0.5	457
W0181W	<2	2.2	0.51	2.4	<0.05	0.56	31	<0.0007	0.29	<0.5	458

Table A4.--Listing of analytical data for samples of moss collected at three Frisian Islands, Germany.

[Results reported on a dry-weight basis; <, less than; ---, not deternined]

Sample ID	Latitude	Longitude	Ash, %	Al, %	As, ppm	Ba, ppm	Ca, %	Ce, ppm	Co, ppm	Cr ppm
					Amrum					
A0311H	543919	82001	48.3	0.38	0.60	72	0.22	17	---	4.8
A0321H	543918	82006	26.1	0.22	0.26	50	0.23	3.9	---	2.9
A0331H	543904	82020	8.24	0.12	0.16	22	0.28	<1.	0.33	1.9
A0332H	543904	82020	7.45	0.13	0.24	23	0.36	1.7	0.30	2.2
					Baltrum					
B0251H	534354	72453	7.11	0.11	0.13	29	0.59	3.0	0.36	2.4
B0281H	534338	72351	11.3	0.12	0.15	25	0.41	1.9	1.1	2.7
B0282H	534338	72351	13.5	0.15	0.15	26	0.36	3.0	0.95	2.4
					Langeoog					
L0191H	534507	73522	8.75	0.11	0.12	22	0.28	1.6	0.26	1.8
L0192H	534507	73522	9.24	0.11	0.10	25	0.33	1.5	0.28	2.6
L0211H	534509	73447	22.6	0.22	0.24	41	0.27	2.9	---	2.7
L0212H	534509	73447	21.5	0.22	0.26	37	0.26	6.9	---	4.7
L0221H	534503	73203	7.42	0.066	0.07	15	0.33	<1	0.52	1.4
L0222H	534503	73203	6.19	0.056	0.09	13	0.31	<1	0.50	1.2
L0241H	534520	73210	14.0	0.15	0.14	28	0.28	4.3	0.42	2.4

Table A4.--Listing of analytical data for samples of moss collected at three Friesian Islands, Germany (contnued).

Sample ID	Cu, ppm	Fe, %	Hg, ppm	K, %	La, ppm	Li, ppm	Mg, %	Mn, ppm	Na, %	Nd, ppm
					Amrum					
A0311H	4.8	0.30	0.08	0.34	8.7	---	0.068	159	0.10	9.2
A0321H	11	0.14	0.11	0.29	1.8	---	0.094	94	0.083	<2
A0332H	13	0.074	0.14	0.24	1.1	0.60	0.11	171	0.057	<2
A0331H	10	0.072	0.14	0.20	0.74	0.58	0.091	140	0.050	<2
					Baltrum					
B0251H	14	0.071	0.13	0.18	1.8	0.71	0.15	135	0.044	<2
B0281H	7.9	0.067	0.12	0.23	1.2	0.57	0.12	113	0.056	<2
B0282H	6.5	0.082	0.13	0.22	1.8	0.68	0.11	113	0.058	<2
					Langeoog					
L0191H	5.9	0.065	0.11	0.26	0.96	0.61	0.11	105	0.049	<2
L0192H	6.7	0.069	0.12	0.31	1.0	0.65	0.12	111	0.055	<2
L0211H	5.7	0.10	0.11	0.27	1.8	1.1	0.08	61	0.081	<2
L0212H	4.7	0.12	0.10	0.26	3.4	1.1	0.080	67	0.077	3.7
L0221H	7.2	0.040	0.10	0.29	0.59	0.45	0.13	96	0.049	<2
L0222H	6.8	0.029	0.10	0.28	0.56	0.37	0.12	93	0.045	<2
L0241H	6.6	0.099	0.14	0.27	2.2	0.84	0.11	154	0.064	2.7

Table A4.--Listing of analytical data for samples of moss collected at three Friesian Islands, Germany (contnued).

Sample ID	Ni, ppm	P, %	Pb, ppm	Se, ppm	S-total, %	Sr, ppm	Ti, %	V, ppm	Y, ppm	Zn, ppm
					Amrum					
A0311H	---	0.044	14	0.29	0.08	24	0.14	6.3	2.4	13
A0321H	1.6	0.047	13	0.37	0.10	22	0.06	3.7	---	19
A0332H	1.7	0.097	15	0.42	0.16	28	0.011	3.6	<0.5	33
A0331H	1.5	0.078	12	0.42	0.16	23	0.017	3.0	<0.5	26
					Baltrum					
B0251H	1.5	0.078	20	0.39	0.15	50	0.011	3.6	0.57	46
B0281H	1.6	0.096	12	0.34	0.14	34	0.012	3.1	0.57	77
B0282H	1.5	0.084	11	0.34	0.14	31	0.023	3.1	0.81	68
					Langeoog					
L0191H	1.4	0.080	14	0.42	0.14	21	0.016	3.2	<0.5	35
L0192H	1.6	0.092	18	0.41	0.15	24	0.015	3.6	<0.5	42
L0211H	1.1	0.070	14	0.30	0.12	27	0.032	3.4	1.1	25
L0212H	1.3	0.062	10	0.34	0.11	24	0.045	3.7	1.1	24
L0221H	1.2	0.10	8.2	0.25	0.12	26	0.0074	1.9	<0.5	89
L0222H	1.1	0.099	8.0	0.25	0.12	25	0.0025	1.7	<0.5	80
L0241H	1.3	0.066	9.9	0.34	0.13	25	0.034	3.2	1.1	24

Table A5.--Listing of analytical data for samples of sediments collected at a tidal marsh.

[<, less than; ---, not determined]

Sample ID	Latitude	Longitude	pH, std.	Al, %	As, ppm	Ba, ppm	Be, ppm	C-total, %	Ca, %	Ce, ppm
MSH 0071	534257	75825	7.6	5.0	24	32	2	4.97	6.0	60
MSH 0081	534256	75827	---	4.8	20	30	2	4.12	5.0	53
MSH 0091	534255	75905	7.9	3.0	9.7	29	1	2.18	3.2	43
MSH 0101	534256	75907	---	2.9	9.1	26	<1	2.18	3.8	38
MSH 0111	534251	80004	8.2	1.5	3.7	17	<1	1.14	2.5	21
MSH 0121	534250	80007	7.8	2.7	9.7	28	<1	1.54	2.6	45

Sample ID	Co, ppm	Cr, ppm	Cu, ppm	Fe, %	Ga, ppm	Hg, ppm	K, %	La, ppm	Li, ppm	Mg, %
MSH 0071	11	94	17	3.2	13	0.68	1.8	33	49	1.2
MSH 0081	11	89	18	3.0	12	0.34	1.8	29	46	1.1
MSH 0091	6	51	8	1.5	7	1.6	1.4	24	22	0.61
MSH 0101	6	49	8	1.4	7	0.22	1.3	21	22	0.52
MSH 0111	3	19	4	0.57	<4	0.12	0.78	13	10	0.20
MSH 0121	5	45	4	1.3	5	0.20	1.2	24	18	0.49

Sample ID	Mn, ppm	Na, %	Nb, ppm	Nd, ppm	Ni, ppm	P, %	Pb, ppm	S-total, %	Sc, ppm	Se, ppm
MSH 0071	150	2.0	<4	29	29	0.20	54	0.68	9	0.7
MSH 0081	110	2.1	5	26	28	0.15	53	0.73	9	0.5
MSH 0091	43	1.4	<4	19	13	0.07	27	0.35	5	0.2
MSH 0101	35	1.3	<4	17	13	0.05	27	0.34	4	0.3
MSH 0111	24	0.58	<4	10	5	0.03	14	0.11	2	0.1
MSH 0121	110	1.1	<4	19	10	0.08	24	0.20	4	0.2

Sample ID	Sr, ppm	Th, ppm	Ti, %	V, ppm	Y, ppm	Yb, ppm	Zn, ppm
MSH 0071	27	9	0.29	96	17	2	150
MSH 0081	23	8	0.27	92	16	2	140
MSH 0091	16	6	0.20	44	11	1	61
MSH 0101	18	4	0.19	43	10	1	66
MSH 0111	14	<4	0.11	18	6	<1	25
MSH 0121	14	5	0.21	37	12	1	51

Table A6.--Listing of analytical data for samples of marsh grass collected at a tidal marsh.

[Results reported on a dry-weight basis; <, less than; ---, not determined]

Sample ID	Latitude	Longitude	Ash, %	Al, %	As, ppm	Ba, ppm	Ca, %	Ce, ppm	Co, ppm	Cr, ppm
M0071S	534257	75826	12.9	0.11	0.50	8.4	0.32	<1	0.26	2.8
M0081S	534257	75827	14.3	0.19	0.66	16	0.41	1.6	0.43	4.4
M0091S	534256	75905	13.2	0.090	0.50	8.7	0.30	<1	0.40	2.5
M0101S	534256	75908	13.3	0.076	0.30	7.6	0.32	<1	---	2.1
M0111S	534251	80005	11.4	0.034	0.20	3.9	0.24	<1	---	1.3
M0121S	534250	80007	11.6	0.026	0.10	3.2	0.21	<1	---	0.93

Sample ID	Cu, ppm	Fe, %	Hg, ppm	K, %	La, ppm	Li, ppm	Mg, %	Mn, ppm	Na, %	Ni, ppm
M0071S	2.7	0.090	0.04	1.4	0.90	1.5	0.28	129	2.5	0.65
M0081S	2.3	0.14	0.01	1.3	1.4	2.4	0.40	114	2.6	1.3
M0091S	2.4	0.078	0.02	1.3	0.79	1.3	0.34	123	2.5	0.66
M0101S	2.4	0.063	0.02	1.3	0.67	1.2	0.35	146	2.5	<0.5
M0111S	1.9	0.033	0.02	1.1	---	0.91	0.29	91	2.3	<0.5
M0121S	3.5	0.023	0.02	1.4	---	0.70	0.22	100	2.3	<0.5

Sample ID	P, %	Pb, ppm	S-total, %	Sr, ppm	Ti, %	V, ppm	Y, ppm	Zn, ppm
M0071S	0.32	2.1	0.37	34	0.0039	2.6	0.53	26
M0081S	0.36	3.3	0.46	41	0.0086	4.4	0.57	27
M0091S	0.30	2.0	0.42	34	0.0040	2.1	0.53	26
M0101S	0.35	2.1	0.40	36	0.0027	1.9	0.53	25
M0111S	0.26	1.0	0.35	30	0.0023	0.79	0.53	25
M0121S	0.30	1.1	0.33	26	---	0.58	0.53	27

Table A7.--Listing of analytical data for samples of sandorn and reindeer lichen collected at two Frisian Islands, Germany.

[Results reported on a dry-weight basis; <, less than; ---, not detected]

Sample ID	Latitude	Longitude	Ash, %	Al, %	As, ppm	Ba, ppm	Ca, %	Ce, ppm	Co, ppm	Cr, ppm
					Langeoog--Reindeer Lichen					
L0191C	534507	73522	6.02	0.072	0.22	11	0.06	1.3	0.18	1.3
					Wangerooge--Reindeer Lichen					
W0151C	534716	75611	16.5	0.16	0.16	26	0.099	3.3	---	3.1
					Wangerooge--Sandorn					
W0131R	534702	75659	3.45	0.0038	<0.05	1.2	0.72	<1	0.10	0.41
W0141R	534703	75655	3.54	0.0046	0.05	2.2	0.71	<1	0.18	0.50
W0151R	534716	75611	4.13	0.0037	<0.05	1.4	0.91	<1	0.12	0.37

Sample ID	Cu, ppm	Fe, %	Hg, ppm	K, %	La, ppm	Li, ppm	Mg, %	Mn, ppm	Na, %	Ni, ppm
					Langeoog--Reindeer Lichen					
L0191C	1.9	0.045	0.15	0.072	0.66	0.42	0.026	19	0.025	0.72
					Wangerooge--Reindeer Lichen					
W0151C	1.7	0.078	0.12	0.13	1.5	0.99	0.035	35	0.050	0.99
					Wangerooge--Sandorn					
W0131R	7.9	0.008	0.04	0.55	0.17	0.72	0.12	35	0.059	2.2
W0141R	5.7	0.012	0.04	0.60	0.21	1.5	0.15	64	0.050	3.9
W0151R	5.8	0.008	0.04	0.54	0.21	0.74	0.18	36	0.041	2.2

Sample ID	P, %	Pb, ppm	Se, ppm	S-total, %	Sr, ppm	Ti, %	V, ppm	Y, ppm	Zn, ppm
					Langeoog--Reindeer Lichen				
L0191C	0.017	7.2	0.38	0.12	6.0	0.0096	1.6	<0.5	14
					Wangerooge--Reindeer Lichen				
W0151C	0.033	8.6	0.30	0.080	11	0.025	2.1	0.66	25
					Wangerooge--Sandorn				
W0131R	0.16	1.2	<0.05	0.22	31	<0.0007	<0.19	<0.5	28
W0141R	0.13	1.8	<0.05	0.23	42	<0.0007	0.21	<0.5	35
W0151R	0.14	1.7	<0.05	0.24	36	<0.0007	<0.19	<0.5	28