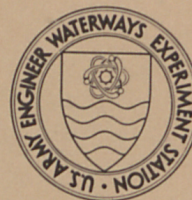
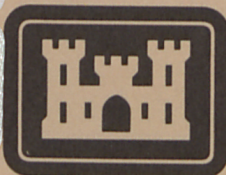


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PLANT BIOASSAY OF MATERIALS FROM THE BLUE RIVER DREDGING PROJECT

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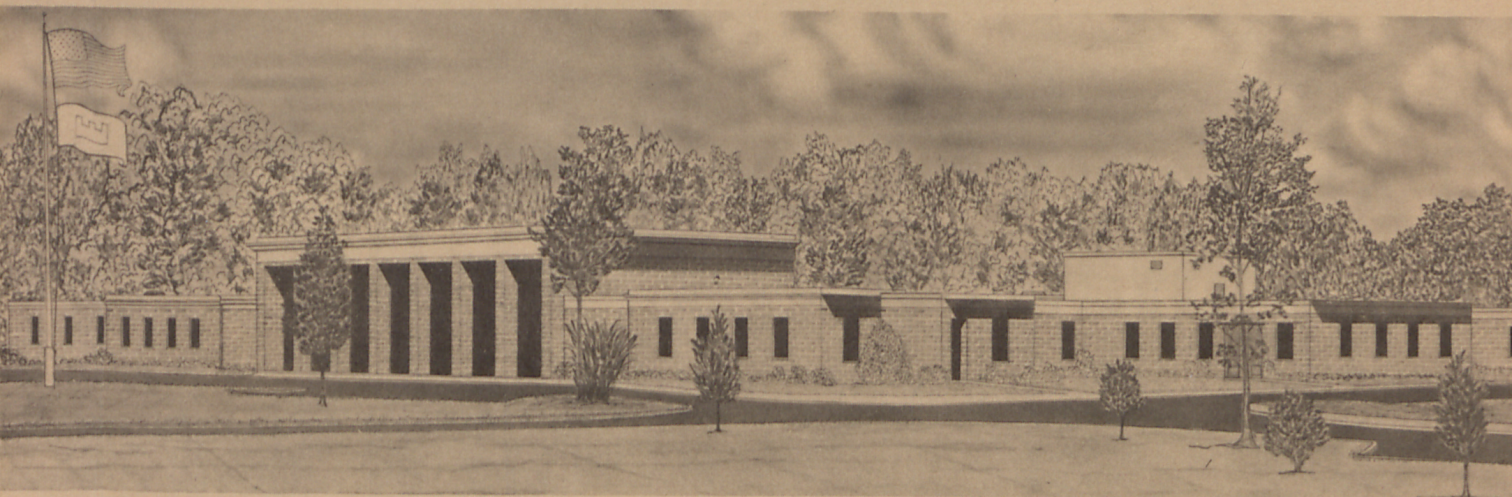
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Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

September 1981

Final Report

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20. ABSTRACT (Continued).

Composite samples were taken of each sediment and soil, placed into polyethylene-lined steel drums, and transported by truck to WES. Each of the sediments and soils was air-dried and mixed well before being placed into plastic buckets. Two complete sets of buckets were prepared. One set was unfertilized while the other set was fertilized with an appropriate amount of nitrogen, phosphorus, and potassium for establishing grass.

Each of the sediment soil treatment combinations was planted to five plant species: Cynodon dactylon (common bermuda grass), Festuca rubra (red fescue), Festuca arundinacea (tall fescue), Poa pratensis (Kentucky bluegrass), and the index plant, Cyperus esculentus. The experiment was replicated three times. Common bermuda grass and C. esculentus were allowed to grow 45 days before harvest. Tall fescue, red fescue, and Kentucky bluegrass were allowed to grow 63 days before harvest. After the respective plant growth periods, the plants were harvested, dried to constant weight at 70°C, digested in nitric acid--red fuming nitric acid, and analyzed for zinc and cadmium. Samples of the air-dried sediment and soil were subjected to extraction by nitric acid, DTPA, and distilled water.

Common bermuda grass had the greatest yield of all the species. Yields of red fescue, tall fescue, and Kentucky bluegrass were low with more than 70 percent of them being less than 0.5 g oven-dry weight. Yield of C. esculentus was somewhat less than common bermuda but much greater than either the fescues or Kentucky bluegrass. Best plant growth for all species was observed on the north bank material. Concentration of cadmium and zinc in the index plant, Cyperus esculentus, was relatively low compared to recent research data collected at the WES. These results indicated that the cadmium and zinc in the river sediments were relatively unavailable. Consequently, concentrations of cadmium and zinc in the other grasses were relatively low.

In general, plant concentrations of cadmium and zinc in common bermuda, red fescue, and Kentucky bluegrass varied in the order of river channel No. 2 sediment > river channel No. 1 sediment > north bank soil > disposal site soil. Tall fescue did not show such pronounced differences; however, the highest concentrations of cadmium and zinc were found in plants grown in river channel No. 2 sediment. Suppressed plant growth on river channel No. 2 sediment resulted in elevated plant concentrations of cadmium and zinc. Since common bermuda grass produced the greatest yield of the grasses tested, it had the greatest total uptake of cadmium and zinc. Red fescue showed some of the lowest plant concentrations and total uptake of cadmium and zinc compared to the other grass species grown on soil from north bank and river channel No. 1 sediment.

Based upon the results of the plant bioassay experiment, river channel No. 2 sediment should be placed on the disposal site first, followed by covering with river channel No. 1 sediment, and then topped with soil from the north bank. Plant cover could be established by planting common bermuda grass and then overseeded with red fescue in the fall. This approach to the disposal of these materials will ensure reduced mobility of the cadmium and zinc in the river sediments. Until additional data are obtained for metal uptake by agricultural crops other than the grass tested in this study, use of the disposal site should be limited to grasses.

PREFACE

This study was conducted at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., from July 1980 to March 1981 by personnel of the Environmental Laboratory (EL) Contaminant Mobility Research Team: Drs. Bobby L. Folsom, Jr., and Charles R. Lee; Ms. Karen M. Preston; and Messrs. T. C. Sturgis, F. Hall, Jr., W. M. Brodie, and D. J. Bates. The report was written by Drs. Folsom and Lee and Ms. Preston.

The study was under the general supervision of Dr. R. M. Engler, Chief, Contaminant Mobility and Regulatory Criteria Group (CMRCG), Mr. D. L. Robey, Chief, Ecosystem Research and Simulation Division, and Dr. J. Harrison, Chief, EL.

Funding for the study was provided by the U. S. Army Engineer District, Kansas City, Kansas City, Mo., and the Office, Chief of Engineers. Project Monitors at the Kansas City District were Ms. N. Tester and Mr. D. L. Jones.

Commander and Director of the WES during the study was COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

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SUMMARY

A plant bioassay and associated chemical analyses were performed on sediment and bank material from the Blue River and soil from a proposed disposal site. The objectives of the tests were to determine the availability and extent of plant uptake of cadmium and zinc that would occur when the dredged material was placed in an upland environment and seeded to grass. In addition, the results of the tests were used to formulate a disposal plan for the materials.

Four grass species were grown on each sediment/soil in the greenhouse: common bermuda, red fescue, tall fescue, and Kentucky bluegrass. Common bermuda grew the best of all the species while red fescue had the lowest concentrations and total uptake of cadmium and zinc. Concentrations of cadmium and zinc in the four grass species were relatively low compared to previous WES research.

Results of the plant bioassay indicate that the disposal site should not be disturbed. The river should be dredged from river channel No. 2 toward river channel No. 1 and the material placed on the disposal site such that river channel No. 2 is covered with river channel No. 1. The north bank material should be used as the final cover material for the disposal site.

PLANT BIOASSAY OF MATERIALS FROM THE
BLUE RIVER DREDGING PROJECT

PART I: INTRODUCTION

Background

1. During planning for the entire reach of the Blue River Channel Modification Project (22.5 km), chemical analysis data collected by the Environmental Protection Agency (USEPA 1979) for the river sediments showed potential problems with polychlorinated biphenyls (PCB's) and certain toxic metals, such as cadmium and zinc. These data and the proposed plan for disposal of river sediments were reviewed by personnel of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. Some concern was expressed regarding the enhancement of the bio-availability of cadmium and zinc in the dredged material. Recent research results at the WES have documented a tenfold increase in the uptake of cadmium by plants grown on contaminated sediments placed in an upland environment compared to the uptake of cadmium grown on the same contaminated sediment under flooded conditions. It was decided that an investigation be conducted to collect additional data to better predict the impact of placing these materials in an upland environment.

Scope of Work

2. A standard plant bioassay test and associated chemical analyses were performed on sediment and bank material from a reach of the Blue River which had been identified by EPA testing to have potentially high concentrations of cadmium and zinc. The same tests and analyses were performed on soil from a proposed disposal site, one of several in the area. The objectives of the test were to determine the availability and extent of plant uptake of cadmium and zinc that would occur when the dredged material was placed in an upland environment and seeded to grass. In addition, the results of the tests were to be used to formulate a

suggested disposal plan for the materials such that potentially harmful materials could be separated from the biologically active areas.

PART II: METHODS AND MATERIALS

Field Techniques

Sediment-soil location

3. Locations of composite samples taken of each sediment and soil are illustrated in Figure 1. The Blue River was sampled at two places. Bank material was sampled from the north bank, across from one of the river channel (RC) sample sites. Soil from one of the proposed disposal sites was also sampled.

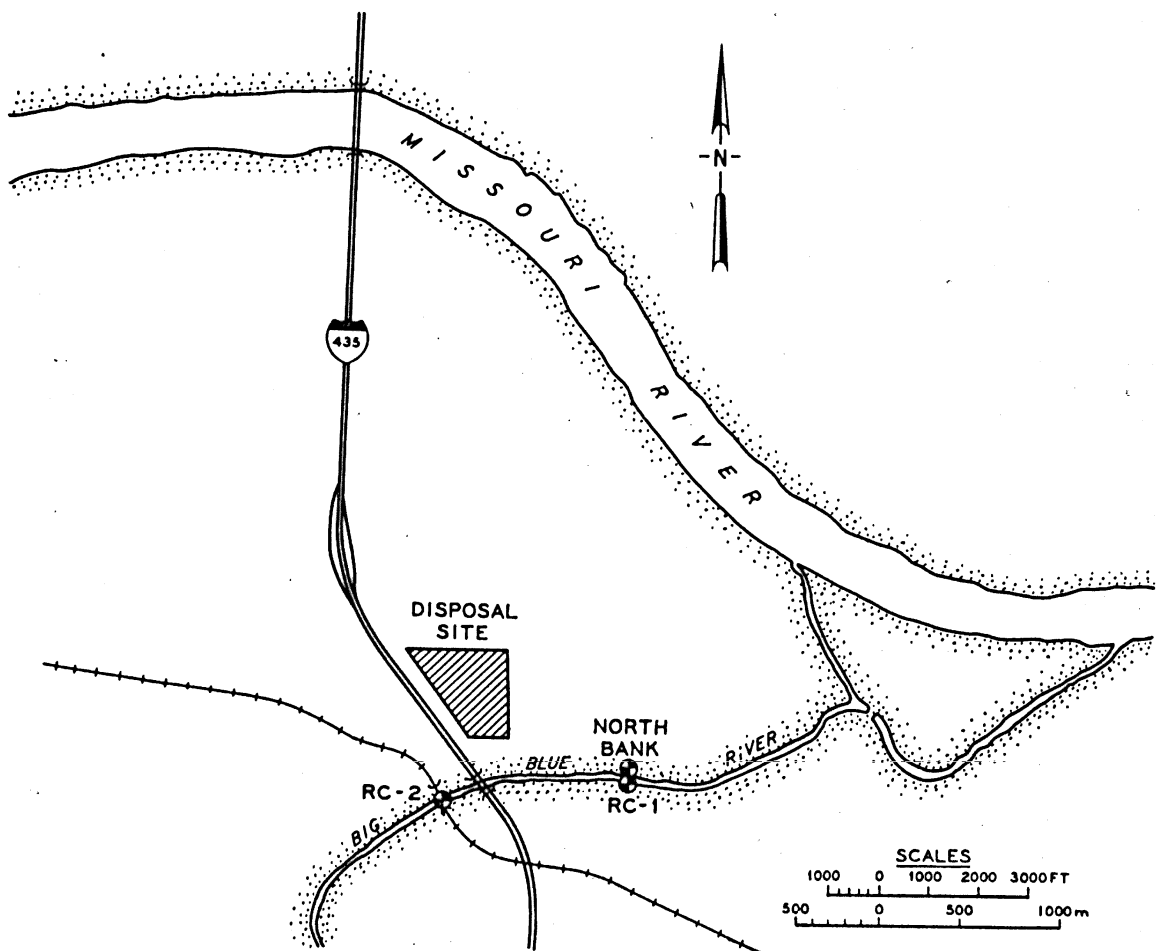


Figure 1. Sediment and soil sample locations for the Blue River plant bioassay

Sampling and handling

4. River channel sediments were taken with a dragline sampler.

The bucket on the dragline was positioned over the middle of the channel and lowered into the water. On bottom impact, it was dragged back along the bottom until reaching the bank. The bucket was raised out of the water, positioned over a 208-ℓ (55-gal) drum lined with polyethylene, and the sediment poured into the drum. The bucket removed a 75- by 61- by 30-cm volume of sediment with each drag. Four such drags filled the drum. The dragline sampler was moved upstream 15 m where a duplicate drum was filled by the same procedure. These drums represented the sediment sample river channel No. 1 (RC-1). The sampler was moved upstream 450 m where the procedure was repeated to collect two more drums of sediment. These samples represented the sediment sample river channel No. 2 (RC-2).

5. The bank material was sampled using a churn drill sampler. A churn drill pushed a 12.7- by 91.4-cm tube into the soil to a depth of 3.05 m. The soil inside the tube was deposited into a drum lined with polyethylene as described above. The drill sampler was moved 50 cm and another 3.05-m bank sample was taken and placed into the drum. This procedure was repeated until the drum was full (a total of four times). The drill sampler was moved 15 m upstream where a duplicate drum was filled using the same procedure.

6. The above sampling methods for bank and river channel materials resulted in a composite sample of the material that is to be removed during the dredging project. The bank will be excavated to a depth (thickness) down to the waterline of approximately 3.05 m, the river channel to a depth of 1.5 m.

7. The proposed disposal site was sampled using a shovel and a small plastic bucket. Random soil samples were taken and deposited into duplicate 208-ℓ drums. The 208-ℓ drums were also prepared as described above.

8. Sediments and soils were collected on 26 June 1980. Two 208-ℓ drums of each sediment or soil provided a sufficient quantity of material to conduct the standard plant bioassay test. The drums were sealed with airtight lids and transported by truck to the WES.

Standard Plant Bioassay Tests

Experimental design

9. The experimental design was a randomized complete-block and included the four materials from the Blue River plus a WES reference soil, five plant species, fertilizer addition versus no fertilizer addition, and upland disposal condition, each replicated three times.

Sediment preparation

10. Upon arrival at the WES (30 June 1980), the sediments/soils were placed into 2-m by 2-m by 14-cm wooden drying flats lined with a sheet of polyethylene. Each of the sediments/soils was mixed well after being placed into the drying flats, a 1-l plastic sample bottle was filled with each material collected, and the sediments/soils were allowed to air dry. The sediments/soils were turned twice daily so that they dried as evenly as possible.

11. The air-dried soils were subsequently ground in a Kelly Duplex grinder (The Duplex Mill and Manufacturing Company, Springfield, Ohio) to pass a 2-mm screen and mixed well before being placed into plastic buckets. The river sediments were coarse sands and gravels, hence grinding and screening were not necessary. Two complete sets of experimental units were prepared. One set was unfertilized while the other set was fertilized with $100 \mu\text{g g}^{-1}$ of nitrogen (N) as ammonium sulfate, $100 \mu\text{g g}^{-1}$ phosphorus (P) as sodium phosphate, and $100 \mu\text{g g}^{-1}$ potassium (K) as potassium chloride.

Experimental unit

12. A schematic diagram of the standard plant bioassay apparatus is shown in Figure 2. A small inner bucket rested on polyvinyl chloride (PVC) pipe inside a larger outer bucket. Six 6.35-mm-diam holes were drilled in the bottom of the inner bucket; these were covered with a 2.54-cm polyurethane sponge overlaid with a 2.54-cm layer of washed quartz sand. The sand and sponge acted as a filter to keep the sediment/soil from draining out the bottom of the small bucket. Holes in the small bucket also allowed water movement into and out of the sediment/soil.

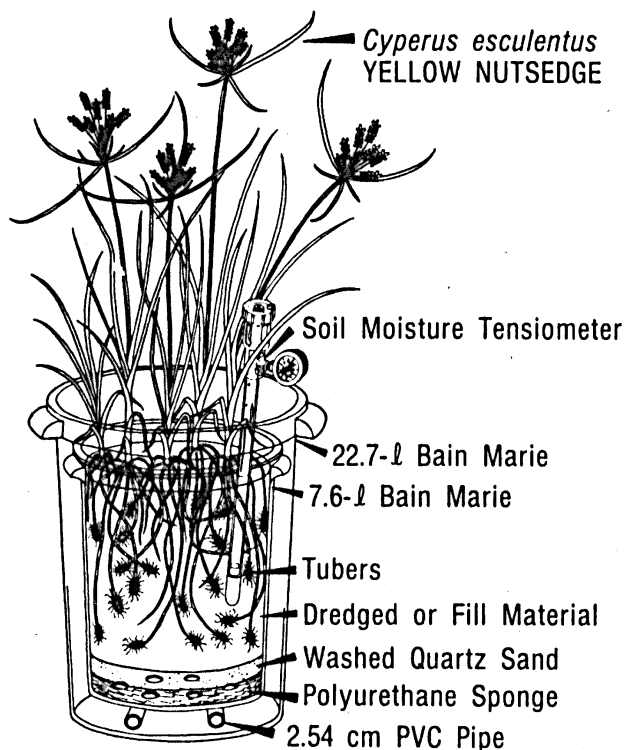


Figure 2. Schematic of the experimental unit used for the Blue River plant bioassay

13. After the sediment/soil had been placed into the container, a soil moisture tensiometer was inserted into each sediment/soil for the measurement of soil moisture.

Water supply

14. The source of water used in the experiment was deionized water obtained from a Continental Model 3230 Reverse Osmosis (RO) water system.

Greenhouse environment

15. The plant growth portion of the experiment was conducted from mid-July 1980 to mid-October 1980. The temperature regime of the greenhouse was maintained at 32.2°C daytime maximum and 21.1°C nighttime minimum. Relative humidity generally varied from 50 percent at maximum daytime temperature to near 100 percent at nighttime temperature minimum. Day length varied from 14 hr in July to 11.5 hr in mid-October. No supplemental artificial lighting was used.

Sediment disposal condition

16. A recent WES study (Folsom, Lee, and Bates 1981) indicated that certain toxic metals, especially cadmium and to a lesser extent zinc, were more plant available under an oxidized-upland moisture regime. Therefore, the water regime of the sediment/soil was maintained between the freely draining-unbound water situation and field capacity (0.0 percent and 33.3 percent reading on the tensiometer, respectively). This represented an upland disposal condition. When watering was necessary, the procedure was as follows: the water level in the outer pot was brought up to the level of sediment in the inner pot and allowed to stand until the tensiometer read 0.0 percent. During this time, water entered the sediment through the holes in the bottom of the container (Figure 2). After the 0.0 percent reading was obtained, the water was completely siphoned out of the large container and any water remaining in the sediment was allowed to drain out the bottom of the inner container.

Plants

17. Three of the plant species used are commonly grown in the Kansas City area and included: Cynodon dactylon (common bermuda grass), Festuca arundinacea (tall fescue), and Poa pratensis (Kentucky bluegrass). Another species, Festuca rubra (red fescue), was grown because it has been shown to take up much less heavy metals than the other three species. The WES index plant, Cyperus esculentus, was grown to allow comparison of heavy metal uptake with other WES data on heavy metal uptake.

Planting, growing, and harvesting techniques

18. Seeds of common bermuda, tall fescue, red fescue, and Kentucky bluegrass were planted at seeding rates recommended by the Missouri Agricultural Experiment Station for the Kansas City area and are shown in Table 1. The seeds were planted by first weighing out the appropriate quantity into a plastic weighing dish and then spreading the seeds on the surface of the sediment/soil in the bucket. Five tubers of C. esculentus were planted in each bucket. A 0.5-cm layer of

sediment/soil that had been previously removed from each bucket was spread evenly over the seeds, the sediment surface sprayed gently with water, and then the bucket capped with its included lid until seed germination occurred. After germination, the lids were permanently removed. Common bermuda and C. esculentus were allowed to grow 45 days before harvest. Tall fescue, red fescue, and Kentucky bluegrass were allowed to grow 63 days before harvest. After the respective plant growth periods, the aboveground plant material was harvested, rinsed with RO water, blotted with paper towels, and dried to constant weight at 70°C. Aboveground plant yield was composed of leaves, stems, seeds, and dead leaf tissue. Only the plant leaves were ground into a coarse powder with a Wiley mill (Model No. 4) and analyzed for metals.

Laboratory Procedures

Chemical analysis of plant material

19. An aliquot of powdered leaf material of each of the five species was digested and analyzed for the acid-digestable metals zinc (Zn) and cadmium (Cd). Samples of standard orchard leaves (National Bureau of Standards SRM-1571) were also digested and analyzed for zinc and cadmium to estimate effectiveness of the acid digestion procedure.

Nitric acid digestion

20. The nitric acid digestion was accomplished by the following procedure. Two grams of oven-dried plant material (weighed by difference to the nearest 0.1 mg) was placed into a 100-ml micro-Kjeldahl flask. Fifteen millilitres of concentrated nitric acid was added, the mixture placed on a digestion rack, heated until almost dry, and then allowed to cool to room temperature. Five millilitres of red fuming nitric acid was then added and the solution was heated to, almost dryness. The mixture was allowed to cool to room temperature and was diluted with 30 ml 1.2 N hydrochloric acid (HCl). The solution was quantitatively transferred into a 50-ml volumetric flask with 1.2 N HCl, filtered through Whatman No. 42 filter paper, and diluted to volume with 1.2 N HCl.

Chemical analysis of sediments

21. All sediments/soils were extracted with a diethylenetriamine-pentaacetic acid (DTPA) procedure (Lee, Sturgis, and Landin 1976) to estimate plant available concentrations of cadmium and zinc. The sediments/soils were also subjected to an acid digest (Folsom, Lee, and Bates 1981) for an estimate of total quantities of cadmium and zinc. The sediments/soils were also subjected to a distilled water leach (modified elutriate test, 1 volume sediment plus 4 volumes distilled water). Other chemical parameters determined on the sediments/soils included total Kjeldahl nitrogen (TKN), total phosphorus and potassium, calcium carbonate equivalent, wet and dry pH, and total sulfur.

PART III: RESULTS AND DISCUSSION

Sediment Physical and Chemical Parameters

22. Selected chemical and physical parameters of the sediments and soils are presented in Table 2. A complete list of the data is presented in Appendix A. Both river sediments were coarser, had higher pH's, and had greater calcium carbonate (CaCO_3) equivalents than either north bank or disposal site soils. The river channel materials were considered coarse calcareous sands while the north bank soil was considered to be a calcareous loam, and the disposal site soil a calcareous clay. The result of fertilizer addition for agricultural crop production was reflected in the increased levels of TKN, total phosphorus (HNO_3TP), and total potassium (HNO_3K). All of these concentrations, however, were well within the normal range generally found in sediments/soils (Folsom, Lee, and Bates 1981). The reduced nature of the flooded river channel sediments was reflected in their higher total sulfur (Total S) contents compared to north bank and disposal site soils.

Extractable Heavy Metals

23. The toxic metals cadmium and zinc in the sediments/soils extractable by DTPA, nitric acid (HNO_3), and distilled water are presented in Table 3. The river sediments generally contained more cadmium and zinc than the north bank or disposal site soils. The cadmium content of the river sediments was approximately one half that reported by USEPA (1979). These lower values may be a result of a composite sample being collected with a drag line across the width of the river channel whereas the EPA samples consisted of a shallower grab sample at each location in the river. Cadmium extractable by DTPA, however, indicated that the cadmium present in the river channel sediments would have limited plant availability.

24. Water-extractable concentrations of cadmium (Table 3) were very low. Water-extractable zinc from the Blue River materials was also

very low. These low water-extractable values indicated that the cadmium and zinc in the Blue River materials were not water soluble and therefore should have very restricted mobility out of these materials.

Plant Growth

25. Plant growth of common bermuda on the sediments/soils from the Blue River and the reference sediment (Openwood Lake) is shown in Figure 3. Plant growth on the Blue River materials was less than that on the reference sediment. Plant growth on north bank soil and river channel No. 1 sediment was greater than that on river channel No. 2 sediment or disposal site soil. The soil from the disposal site did not support growth of common bermuda. The presence of herbicides applied for weed control could explain the lack of growth of common bermuda on disposal site soil.

26. Growth of the WES index plant, C. esculentus, was similar to that of common bermuda except that growth did occur on the disposal site soil (Figure 4).

27. Plant growth (and even survival) of red fescue, tall fescue, and Kentucky bluegrass was much less than that of either common bermuda or C. esculentus.

Plant Yield

28. Yield data for the four plant species and the WES index plant are presented in Table 4. Each species was grown on sediments/soils that had been amended with N, P, and K fertilizer. All species (except C. esculentus) were grown on the same materials (except Openwood Lake) without the N, P, and K fertilizer addition.

29. The data presented in Table 4 indicate that common bermuda had the highest yield of all the species. Yields of red fescue, tall fescue, and Kentucky bluegrass were lower with more than 70 percent of them being less than 0.5 g oven-dry weight. Yield of C. esculentus was somewhat less than common bermuda but much greater than either red or



Figure 3. Growth of common bermuda grass on sediments and soils from the Blue River, Kansas City, Mo., and reference sediment from Openwood Lake, Vicksburg, Miss.



Figure 4. Growth of *C. esculentus* on sediments and soils from the Blue River, Kansas City, Mo., and reference sediment from Openwood Lake, Vicksburg, Miss.

tall fescue or Kentucky bluegrass (even though red and tall fescue and Kentucky bluegrass were allowed to grow 18 days longer than C. esculentus and common bermuda). The addition of fertilizer increased the yield of common bermuda but did not increase the yield of the other species.

30. Seed germination and initial growth of red fescue, tall fescue, and Kentucky bluegrass were extremely slow. This was a result of the seed used, species characteristics, and greenhouse growth environment and not due to any phytotoxic effect due to the materials from the Blue River. The poor yield of these species in the Openwood Lake reference sediment supports this conclusion.

Plant Concentrations of Cadmium and Zinc

31. Concentrations of cadmium and zinc in tissue of the five plant species are illustrated in Table 5. Concentrations of cadmium in the index plant, C. esculentus, varied from $0.477 \mu\text{g g}^{-1}$ on north bank soil to $0.919 \mu\text{g g}^{-1}$ on river channel No. 2 sediment. This range in cadmium concentration was lower than that found in a previous WES study (Folsom, Lee, and Bates 1981) for C. esculentus where cadmium concentrations ranged from around $1.0 \mu\text{g g}^{-1}$ up to $20.8 \mu\text{g g}^{-1}$. The upland fertilized condition used in the present study would represent a situation where maximum plant concentration of cadmium would be expected to occur (Folsom, Lee, and Bates 1981). However, as indicated above, cadmium in the index plant grown in this study was much lower compared to the results of the WES study, indicating that the cadmium in the Blue River sediments (especially the river channel sediments) was relatively unavailable for plant uptake. Consequently, cadmium in the other grass species should also be low.

32. Concentration of zinc in the index plant varied from a low of $66.7 \mu\text{g g}^{-1}$ on river channel No. 2 sediment to a high of $124.1 \mu\text{g g}^{-1}$ on disposal site soil. This range in zinc concentration was also on the low end of zinc concentrations in C. esculentus found in the previous WES study. Therefore, zinc in the other plant species should also be expected to be low.

33. Cadmium and zinc concentrations in tall fescue were generally lower than those found for this same species in several other studies. Tall fescue grown on dredged material used in an area strip mine reclamation study in Illinois (Perrier, Llopis, and Spaine 1980) had a mean cadmium concentration of $0.44 \mu\text{g g}^{-1}$ and an average zinc concentration of $196.5 \mu\text{g g}^{-1}$. The mean cadmium concentration in fescue grown on the same site a year later was $0.73 \mu\text{g g}^{-1}$ and ranged up to $2.55 \mu\text{g g}^{-1}$; the mean zinc concentration was $67.3 \mu\text{g g}^{-1}$ and ranged up to $227.7 \mu\text{g g}^{-1}$ (Simmers et al. 1981). Alloway and Davies (1971) found zinc concentration in fescue grown on contaminated mine spoil to range from 65.0 to $350 \mu\text{g g}^{-1}$. Palazzo (1977) found cadmium and zinc concentrations in tall fescue grown on sewage sludge amended soils to be 0.97 and $107 \mu\text{g g}^{-1}$, respectively.

34. Few data on cadmium and zinc concentrations on Kentucky bluegrass or red fescue exist in the literature. Palazzo (1977), in a study on reclamation of acid dredged soils amended with sewage sludge and lime, found Kentucky bluegrass to contain between 0.44 and $0.58 \mu\text{g g}^{-1}$ cadmium and 69 to $89 \mu\text{g g}^{-1}$ zinc. The cadmium and zinc content of Kentucky bluegrass in the present study was higher than that found by Palazzo (1977) with the cadmium concentration in the Kentucky bluegrass grown on the river channel No. 2 sediment being as high as $1.907 \mu\text{g g}^{-1}$. The higher concentrations of cadmium and zinc in the present study were a result of restricted growth and low yields of Kentucky bluegrass. Palazzo (1977) found that the concentration of cadmium in red fescue was less ($0.36 \mu\text{g g}^{-1}$) than in either tall fescue ($0.97 \mu\text{g g}^{-1}$) or Kentucky bluegrass ($0.44 \mu\text{g g}^{-1}$). No data could be found on cadmium and zinc concentrations in common bermuda grass.

35. In general, plant concentrations of cadmium and zinc in common bermuda, red fescue, and Kentucky bluegrass varied in the order of river channel No. 2 sediment > river channel No. 1 sediment > north bank soil > disposal site soil. Tall fescue did not show such pronounced differences; however, the highest concentrations of cadmium and zinc were found in plants grown in river channel No. 2 sediment. Considering both fertilized and unfertilized materials, red fescue had the lowest

concentrations of cadmium and zinc compared to the other grass species.

36. It is extremely difficult to extrapolate the metal uptake data from the grasses tested in this study to other plant species. Data on toxic metal uptake from dredged material by agricultural crops are limited. Lee, Engler, and Mahloch (1976) reviewed this available information. They discussed information from Dutch researchers that indicated more uptake of cadmium from contaminated dredged material by certain leafy agricultural crops such as lettuce and radish leaves than of other crops such as wheat (Figure 5). Assuming cadmium uptake by wheat is comparable to the grasses used in the present study and based on the Dutch data, it is conceivable that if leafy vegetables were grown on the Blue River dredged material that they might take up more cadmium than the grasses tested in this study. Additional testing is required to determine the validity of these assumptions.

37. There is considerable information on toxic metal uptake from sewage sludge amended soils. Assuming that toxic metal availability from sludges is comparable to dredged material, leafy vegetables grown on sewage sludges have been reported to take up rather large concentrations of cadmium. Chaney and Giordano (1977) have compared cadmium uptake by a leafy vegetable like swiss chard to that of soybeans grown on cadmium-contaminated, sludge-amended soil. Examples of the relative concentrations of cadmium in these crops were reported as 7.0 $\mu\text{g/g}$ Cd in swiss chard leaves compared to 5.7 $\mu\text{g/g}$ Cd in soybean leaves and 2.6 $\mu\text{g/g}$ Cd in soybean grain. These data suggest that the relative Cd uptake from Cd-contaminated media might be leafy vegetables most, wheat and grasses least, and soybeans somewhere in between. The preceding discussion of the present test results with available literature is extremely difficult to substantiate without additional plant bioassay testing. However, until additional data are obtained on metal uptake by agricultural crops other than the grasses tested in this study, the use of the disposal site receiving the Blue River sediments should be limited to grasses.

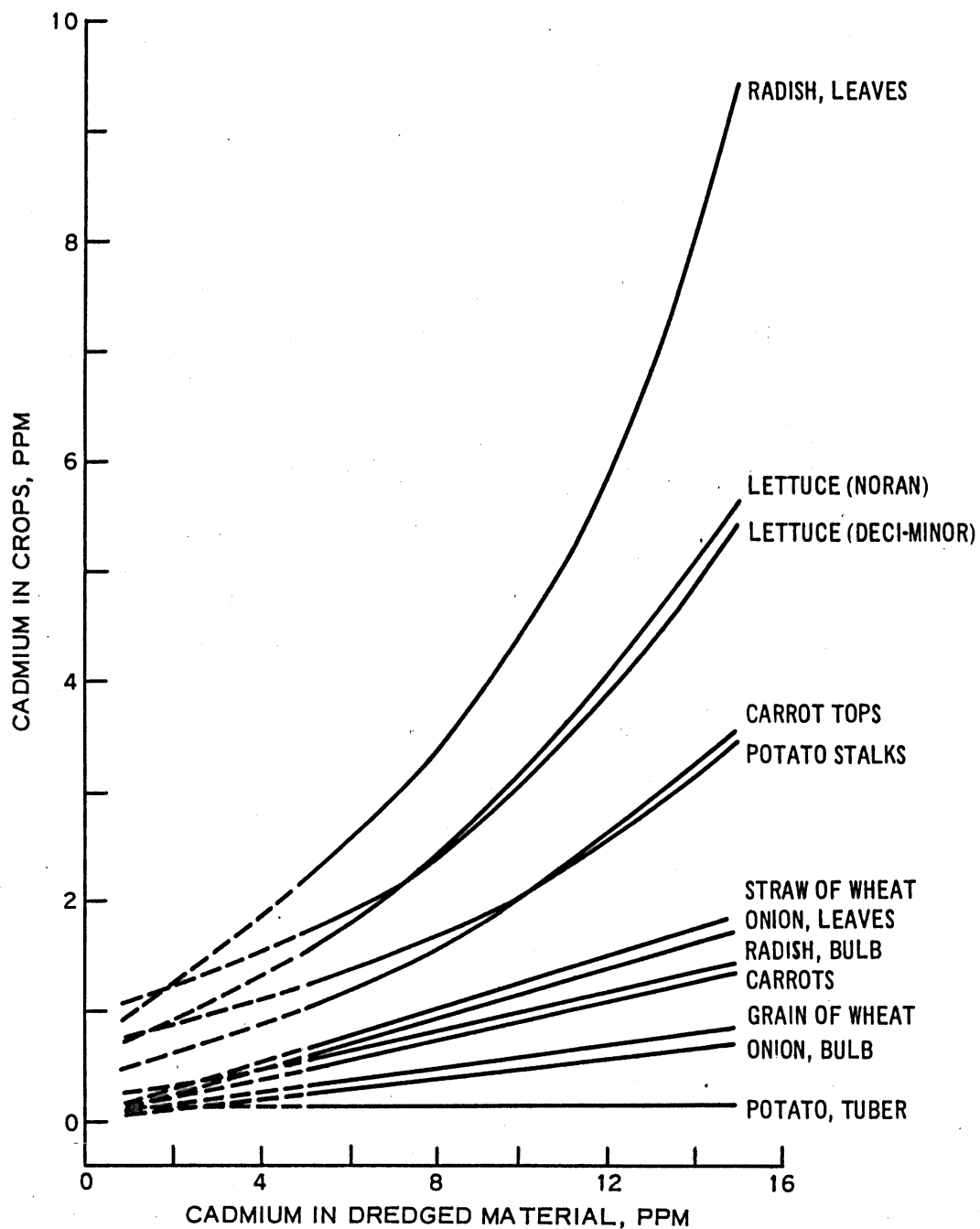


Figure 5. Relationship between the amount of total cadmium in dredged material and the amount in the crops cultivated on it

Total Plant Uptake of Cadmium and Zinc

38. Total plant uptake (concentration times aboveground yield) represents the actual amount of heavy metals potentially mobilized to the environment. Even though one plant species may have a lower heavy metal concentration than another plant species, the total yield of the plant with the lower heavy metal concentration may be much greater than the plant species with the higher heavy metal concentration (i.e., a dilution effect due to increased plant growth). Therefore, total plant uptake must be considered as well as plant concentration.

39. Total plant uptake of cadmium and zinc by the test species and the WES index plant is illustrated in Table 6. Suppressed plant growth on river channel No. 2 sediment resulted in elevated plant concentrations of cadmium and zinc (i.e., the highest plant concentrations of cadmium and zinc in plants grown on river channel No. 2 sediment did not result in the highest total uptake). Plant growth was much better on north bank soil compared to the other sediments/soils, which resulted in higher total plant uptake of cadmium and zinc. Since common bermuda produced the greatest yield of the grasses tested, it had the greatest total uptake of cadmium and zinc. Red fescue showed some of the lowest plant concentrations and total uptake of cadmium and zinc compared to those of the other grass species, even on river channel No. 2 sediment.

40. While the data in Table 6 show statistically significant increases in total uptake of cadmium and zinc by common bermuda and C. esculentus, the values are very low (micrograms per pot). This indicates relatively low mobility of these toxic metals into grasses grown on the sediments to be dredged from the Blue River.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

41. A plant bioassay and associated chemical tests were performed on sediment and bank material from the Blue River and soil from a proposed disposal site. The objectives of the test were to determine the availability and extent of plant uptake of cadmium and zinc that would occur when the dredged material was placed in an upland environment and seeded to grass. In addition, the results of the test were used to formulate a suggested disposal plan for the materials.

42. Common bermuda grass had the greatest yield of all the species. Yields of red fescue, tall fescue, and Kentucky bluegrass were low with more than 70 percent of them being less than 0.5 g oven-dry weight. Yield of C. esculentus was somewhat less than common bermuda but much greater than either the fescues or Kentucky bluegrass. Best plant growth for all species was observed on the north bank material.

43. Concentration of cadmium and zinc in the index plant, Cyperus esculentus, was relatively low compared to recent research data collected at the WES. These results indicated that the cadmium and zinc in the river sediments were relatively unavailable. Consequently, concentrations of cadmium and zinc in the other grasses were relatively low.

44. In general, plant concentrations of cadmium and zinc in common bermuda, red fescue, and Kentucky bluegrass varied in the order of river channel No. 2 sediment > river channel No. 1 sediment > north bank soil > disposal site soil. Tall fescue did not show such pronounced differences; however, the highest concentrations of cadmium and zinc were found in plants grown in river channel No. 2 sediment.

45. Suppressed plant growth on river channel No. 2 sediment resulted in elevated plant concentrations of cadmium and zinc. Since common bermuda grass produced the greatest yield of the grasses tested, it had the greatest total uptake of cadmium and zinc. Red fescue showed some of the lowest plant concentrations and total uptake of cadmium and zinc compared to the other grass species grown on soil from north bank

and river channel No. 1 sediment. These total uptake values were still relatively low compared to other grasses grown on contaminated soils and sediments.

Recommendations

46. Based upon the results of the plant bioassay experiment, the proposed disposal site should not be disturbed. The river should be dredged from river channel No. 2 toward river channel No. 1. The material should be placed on the disposal site such that river channel No. 2 is covered with river channel No. 1. The north bank material should be used as the final cover material for the disposal site.

47. Plant cover could be established by planting common bermuda grass in the early summer and then overseeded with red fescue in the fall. This approach to the disposal of these materials will ensure reduced mobility of the cadmium and zinc in the river sediments. Until additional data are obtained on metal uptake by agricultural crops other than the grasses tested in this study, use of the disposal site should be limited to grasses.

REFERENCES

- Alloway, B. J. and Davies, B. E. 1971. "Heavy Metal Content of Plants Growing on Soils Contaminated by Lead Mining," J. Agric. Sci., Camb., Vol 76, pp 321-323.
- Chaney, R. L. and Giordano, P. M. 1977. "Microelements as Related to Plant Deficiencies and Toxicities," Soils for Management of Organic Wastes and Waste Waters, Soil Science Society of America, American Society of Agronomy and Crop Science Society of America, Madison, Wisc.
- Folsom, B. L., Jr., Lee, C. R., and Bates, D. J. 1981. "Influence of Disposal Environment on Availability and Plant Uptake of Heavy Metals in Dredged Material," Technical Report EL-81- (in press), U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- Lee, C. R., Engler, R. M., and Mahloch, J. L. 1976. "Land Application of Dredging, Construction, and Demolition Waste Materials," Land Application of Waste Materials, Soil Conservation Society of America, Ankeny, Iowa.
- Lee, C. R., Sturgis, T. C., and Landin, M. C. 1976. "A Hydroponic Study of Heavy Metal Uptake by Selected Marsh Plant Species," Technical Report D-76-5, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- Palazzo, A. J. 1977. "Reclamation of Acidic Dredge Soils with Sewage Sludge and Lime at the Chesapeake and Delaware Canal," Special Report 77-19, U. S. Army Engineer Cold Regions Research and Engineering Laboratory, CE, Hanover, N. H.
- Perrier, E. R., Llopis, J. L., and Spaine, P. A. 1980. "Area Strip Mine Reclamation Using Dredged Material: A Field Demonstration." Technical Report EL-80-4, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- Simmers, J. W., Folsom, B. L., Jr., Lee, C. R., and Bates, D. J. 1981. "Field Survey of Heavy Metal Uptake by Naturally Occurring Saltwater and Freshwater Marsh Plants," Technical Report EL-81- (in press), U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- United States Environmental Protection Agency. 1977. "Guidelines For the Pollutational Classification of Great Lakes Harbor Sediments," Region V, Chicago, Ill.

Table 1
Recommended Seeding Rates of Levee Establishment of Common Bermuda
Grass, Tall Fescue, Red Fescue, and Kentucky Bluegrass

<u>Grass</u>	<u>Seeding Rate</u>		
	<u>g m⁻²</u>	<u>lb acre⁻¹</u>	<u>g bucket^{-1*}</u>
Common bermuda	7.3	65	0.207
Tall fescue	3.4	30	0.095
Red fescue	3.4	30	0.095
Kentucky bluegrass	1.1	10	0.032

* Seed rate based on 0.028-m² surface area of sediment/soil in the plastic bucket.

Table 2
Selected Chemical and Physical Parameters of Sediments
and Soils from the Blue River, Kansas City, Missouri

Sediment/Soil	Percent			Wet pH	Dry pH	CaCO ₃ Equivalent percent	Total S µg g ⁻¹	TKN µg g ⁻¹	HNO ₃ TP µg g ⁻¹	HNO ₃ K µg g ⁻¹
	Sand	Silt	Clay							
North bank	25.2c*	48.1a	26.7b	7.8b	7.5b	2.6c	320**	319b	659b	1742b
River channel No. 1	80.6b	11.5c	7.9c	8.1a	8.0a	9.9a	1010	178bc	488c	623c
River channel No. 2	96.9a	2.5d	0.6d	8.1a	7.5b	6.0b	950	90c	223d	174d
Disposal site	10.4d	36.3b	53.3a	7.3c	7.0c	0.8d	250	550a	723a	3237a
CV†	8.9	11.5	14.0	1.6	0.7	32.3		69.7	14.5	29.8

* Duncan's Multiple Range Test at $\alpha = 0.05$. Means within each column followed by the same letter are not significantly different at the 5 percent level of probability.

** Only one replicate.

† CV = Coefficient of variation, percent.

Table 3
DTPA, HNO₃, and Water-Extractable Heavy Metals from Sediments
and Soils from the Blue River, Kansas City, Missouri

Sediment/Soil	DTPA Concentration, µg g ⁻¹		HNO ₃ Concentration, µg g ⁻¹		Water Concentration, µg g ⁻¹	
	Cd	Zn	Cd	Zn	Cd	Zn
North bank	0.756b*	75.8b	2.78c	218ab	0.0005c	0.015b
River channel No. 1	0.421d	68.4b	4.07b	253a	0.0010b	0.011c
River channel No. 2	0.525c	98.0a	5.08a	252a	0.0003c	0.007d
Disposal site	0.909a	18.1c	2.88c	186b	0.0016a	0.020a
CV**	14.1	24.6	23.2	26.7	12.8	7.9

* Duncan's Multiple Range Test at $\alpha = 0.05$. Means within each column followed by the same letter are not significantly different at the 5 percent level of probability.

** CV = Coefficient of variation, percent.

Table 4
Yield of Common Bermuda Grass, Red Fescue, Tall Fescue, Kentucky Bluegrass,
and the Index Plant, *Cyperus esculentus*, Grown on Sediments and Soils
from the Blue River, Kansas City, Missouri, and
Openwood Lake, Vicksburg, Mississippi

Sediment/Soil	Yield,* g pot ⁻¹									
	Common Bermuda		Red Fescue		Tall Fescue		Kentucky Bluegrass		C. esculentus	
	Fert**	No Fert†	Fert	No Fert	Fert	No Fert	Fert	No Fert	Fert	No Fert
Openwood Lake	123.05	TN††	0.080	TN	0.484	TN	0.000	TN	29.05	TN
North bank	32.91b‡	16.01b	0.443a	0.568a	1.955a	1.632a	1.725a	1.344a	20.51a	TN
River channel No. 1	49.28a	23.66a	0.053a	0.288a	0.355a	0.977a	0.186a	0.549a	18.80a	TN
River channel No. 2	9.68c	0.30c	0.082a	0.104a	0.191a	0.112a	0.033a	0.056a	8.05b	TN
Disposal site	1.95d	2.41c	0.002a	0.167a	0.721a	2.037a	0.001a	0.021a	6.32a	TN

* Each yield value is a mean of three replicates.

** Fert = 100 µg g⁻¹ N added as (NH₄)₂SO₄, 100 µg g⁻¹ P added as NaH₂PO₄, 100 µg g⁻¹ K added as KCl.

† No Fert = No N, P, or K added.

†† TN = Treatment combination not evaluated.

‡ Duncan's Multiple Range Test at α = 0.05. Means within each column followed by the same letter are not significantly different at the 5 percent level of probability.

Table 5
Leaf Concentration of Cadmium and Zinc in Common Bermuda Grass, Red Fescue,
Tall Fescue, Kentucky Bluegrass, and *Cyperus esculentus* Grown on Sediments
and Soils from the Blue River, Kansas City, Missouri

Sediment/Soil	Concentration, $\mu\text{g g}^{-1}$ *,**									
	Common Bermuda		Red Fescue		Tall Fescue		Kentucky Bluegrass		C. esculentus	
	Cd	Zn	Cd	Zn	Cd	Zn	Cd	Zn	Cd	Zn
<u>Fertilized</u>										
North bank	0.386 ³ _b	23.2 ³ _b	0.330 ¹ _b	16.8 ³ _b	0.700 ³ _a	50.0 ³ _b	0.785 ³ _b	107.7 ³ _b	0.477 ³ _b	85.0 ³ _b
River channel No. 1	0.311 ³ _b	35.0 ³ _b	0.419 ¹ _b	33.8 ¹ _b	0.669 ³ _a	128.5 ³ _a	0.935 ² _b	160.9 ² _a	0.585 ³ _b	89.6 ³ _b
River channel No. 2	0.712 ³ _a	70.0 ³ _a	1.055 ¹ _a	162.1 ¹ _a	0.783 ² _a	143.4 ² _a	1.907 ¹ _a	176.1 ¹ _a	0.919 ³ _a	66.7 ³ _b
Disposal site	0.295 ¹ _b	19.5 ¹ _b	IS†	IS	0.689 ² _a	22.3 ² _b	IS	IS	0.769 ³ _{ab}	124.1 ³ _a
<u>Unfertilized</u>										
North bank	ND††	ND	0.171 ¹ _a	20.6 ¹ _a	0.472 ¹ _a	43.5 ¹ _a	0.650 ² _a	92.9 ² _b	TN‡	TN
River channel No. 1	ND	ND	0.224 ³ _a	48.2 ³ _a	ND	ND	0.666 ¹ _a	145.8 ¹ _a	TN	TN
River channel No. 2	ND	ND	0.241 ¹ _a	43.2 ¹ _a	ND	ND	1.091 ¹ _a	196.2 ¹ _a	TN	TN
Disposal site	0.362 ²	22.6 ²	0.521 ³ _a	23.0 ² _a	0.894 ² _a	38.6 ² _a	1.025 ¹ _a	82.7 ¹ _b	TN	TN

* Duncan's Multiple Range Test at $\alpha = 0.05$. Means within each column followed by the same letter are not significantly different at the 5 percent level of probability.

** Superscript is number of replicates comprising the mean value.

† IS = Insufficient sample for analysis.

†† ND = Not determined.

‡ TN = Treatment combination not evaluated.

Table 6
Total Uptake of Cadmium and Zinc in Common Bermuda Grass, Red Fescue,
Tall Fescue, Kentucky Bluegrass, and *Cyperus esculentus* Grown on
Sediments and Soils from the Blue River, Kansas City, Missouri

Sediment/Soil	Total Uptake, $\mu\text{g pot}^{-1}$,**									
	Common Bermuda		Red Fescue		Tall Fescue		Kentucky Bluegrass		C. esculentus	
	Cd	Zn	Cd	Zn	Cd	Zn	Cd	Zn	Cd	Zn
Fertilized										
North bank	12.56 ³ _a	746 ³ _b	0.34 ¹ _a	14.6 ³ _a	1.11 ³ _a	89.8 ³ _a	1.22 ³ _a	150.9 ³ _a	9.11 _{ab}	1715 ³ _a
River channel No. 1	15.13 ³ _a	1719 ³ _a	0.05 ¹ _a	4.2 ¹ _a	0.32 ³ _a	50.5 ³ _a	0.26 ² _a	44.8 ² _a	10.27 ³ _b	1689 ³ _a
River channel No. 2	7.03 ³ _b	636 ³ _b	0.22 ¹ _a	34.4 ¹ _a	0.22 ² _a	40.5 ² _a	0.19 ¹ _a	17.6 ¹ _a	7.41 ³ _{ab}	542 ³ _b
Disposal site	1.72 ¹ _b	114 ¹ _c	IS†	IS	0.62 ² _a	25.2 ² _a	IS	IS	12.61 _a	1914 ³ _a
Unfertilized										
North bank	ND††	ND	0.19 ¹ _a	23.4 ¹ _a	0.86 ¹ _a	78.8 ¹ _a	1.09 ² _a	159.3 ² _a	TN‡	TN
River channel No. 1	ND	ND	0.06 ³ _a	13.0 ³ _a	ND	ND	0.14 ¹ _a	31.3 ¹ _a	TN	TN
River channel No. 2	ND	ND	0.02 ¹ _a	3.8 ¹ _a	ND	ND	0.08 ¹ _a	14.5 ¹ _a	TN	TN
Disposal site	0.95 ²	56.3 ²	0.08 ³ _a	4.8 ³ _a	2.94 ² _a	109.4 ² _a	0.06 ¹ _a	5.1 ¹ _a	TN	TN

- * Duncan's Multiple Range Test at $\alpha = 0.05$. Means within each column followed by the same letter are not significantly different at the 5 percent level of probability.
- ** Superscript is number of replicates comprising the mean value.
- † IS = Insufficient sample for analysis.
- †† ND = Not determined.
- ‡ TN = Treatment combination not evaluated.

APPENDIX A: BLUE RIVER PLANT BIOASSAY DATA

KANSAS CITY PLANT BIOASSAY DATA

SAMPLE IDENTIFICATION FOR KANSAS CITY STUDY

SEDIMENT

DS DISPOSAL SITE
R1 RIVER CHANNEL 1
R2 RIVER CHANNEL 2
NB NORTH BANK
OP OPENWOOD

GRASS

TF TALL FESCUE
RF RED FESCUE
KB KENTUCKY BLUEGRASS
CB COMMON BERMUDA
CE CYPERUS ESCULENTUS

TREATMENT

F FERTILIZED
U UNFERTILIZED

MISSING VALUES

B BELOW REPORTABLE LIMIT
G NO GROWTH
I INSUFFICIENT MATERIAL
N NOT ANALYZED

OTHER

- LESS THAN (<)

KANSAS CITY PLANT BIOASSAY DATA

SEDIMENT DESCRIPTIVE DATA

COLUMN	DATA
SAMPLEID	SEDIMENT, GRASS, REP
SEDIMENT	SEDIMENT LOCATION
GRASS	GRASS SPECIES
REP	REPLICATE NUMBER
HN03_CD	SEDIMENT TOTAL CADMIUM CONC. (UG/G, ODW)
HN03_K	SEDIMENT TOTAL POTASSIUM CONC (UG/G, ODW)
HN03_ZN	SEDIMENT TOTAL ZINC CONC. (UG/G, ODW)
HN03_TP	SEDIMENT TOTAL PHOSPHORUS CONC(UG/G, ODW)
TKN	SEDIMENT TKN CONC. (UG/G, ODW)
DTPA_CD	SEDIMENT DTPA CADMIUM CONC. (UG/G, ODW)
DTPA_ZN	SEDIMENT DTPA ZINC CONC. (UG/G, ODW)
WET_PH	SEDIMENT PH ON ORIGINAL MATERIAL
DRY_PH	SEDIMENT PH ON AIR DRY MATERIAL (1 TO 2)
SAND	SEDIMENT SAND (%)
CLAY	SEDIMENT CLAY (%)
SILT	SEDIMENT SILT (%)
CAC03	SEDIMENT, CAC03 (% , ODW)

KANSAS CITY PLANT BIOASSAY DATA

SEDIMENT DESCRIPTIVE DATA

SAMPLEID	SEDIMENT	GRASS	REP	HN03_CD	HN03_K	HN03_ZN	HN03_TP	TKN	DTPA_CD	DTPA_ZN	WET_PH	DRY_PH	SAND	CLAY	SILT	CAC03
DSCB1	DS	CB	1	2.744	3229	167	672	461	0.948	18.6	7.20	7.00	7.5	55.0	37.5	0.90
DSCB2	DS	CB	2	2.794	2387	164	657	281	0.933	17.6	7.20	7.00	7.5	55.0	37.5	0.77
DSCB3	DS	CB	3	2.995	3540	181	713	455	0.943	17.9	7.25	7.00	7.5	55.0	37.5	0.62
DSKB1	DS	KB	1	2.694	3379	177	798	1230	0.918	18.3	7.70	7.00	37.5	37.5	25.0	0.44
DSKB2	DS	KB	2	2.794	3530	172	778	228	0.918	18.5	7.70	7.00	7.5	55.0	37.5	0.77
DSKB3	DS	KB	3	2.694	3139	170	773	1140	0.883	17.5	7.70	7.10	7.5	55.0	37.5	0.50
DSRF1	DS	RF	1	2.894	3540	180	708	583	0.883	17.9	7.25	7.00	12.5	52.5	35.0	0.59
DSRF2	DS	RF	2	2.844	3645	186	753	577	0.898	17.9	7.20	7.05	7.5	55.0	37.5	0.68
DSRF3	DS	RF	3	2.844	3109	176	708	304	0.903	17.7	7.20	7.05	7.5	55.0	37.5	1.00
DSTF1	DS	TF	1	3.045	4021	193	773	618	0.878	18.2	7.20	7.00	7.5	55.0	37.5	0.72
DSTF2	DS	TF	2	2.894	3605	180	677	457	0.893	18.5	7.15	7.00	7.5	55.0	37.5	1.22
DSTF3	DS	TF	3	3.345	1716	281	662	263	0.908	17.9	7.20	7.00	7.5	55.0	37.5	1.31
NBCB1	NB	CB	1	2.995	1546	239	682	594	0.808	87.7	7.85	7.50	25.0	27.5	47.5	2.31
NBCB2	NB	CB	2	2.694	1115	308	677	97	0.863	88.2	7.85	7.50	25.0	30.0	45.0	2.54
NBCB3	NB	CB	3	2.644	1776	254	657	285	0.918	89.2	7.85	7.50	25.0	25.0	50.0	2.63
NBKB1	NB	KB	1	3.245	1791	271	693	434	0.888	84.7	7.75	7.50	25.0	25.0	50.0	2.13
NBKB2	NB	KB	2	2.694	1375	240	657	192	0.863	81.7	7.80	7.45	25.0	27.5	47.5	2.43
NBKB3	NB	KB	3	3.045	1746	227	687	268	0.863	87.7	7.80	7.50	25.0	25.0	50.0	2.13
NBRF1	NB	RF	1	2.443	1611	202	647	452	0.678	64.7	7.85	7.50	25.0	25.0	50.0	2.68
NBRF2	NB	RF	2	B	1631	193	607	364	0.663	67.2	7.85	7.55	25.0	30.0	45.0	2.50
NBRF3	NB	RF	3	2.443	1856	177	602	191	0.643	66.7	7.85	7.45	27.5	25.0	47.5	2.70
NBTF1	NB	TF	1	B	1095	164	577	B	0.733	67.7	7.70	7.55	25.0	25.0	50.0	3.32
NBTF2	NB	TF	2	B	2017	164	642	370	0.583	62.7	7.75	7.40	27.5	25.0	47.5	2.90
NBTF3	NB	TF	3	2.794	3344	173	773	263	0.573	60.7	7.70	7.50	22.5	30.0	47.5	3.10
OPCB1	OP	CB	1	0.224	N	116	N	617	0.153	5.8	7.00	5.85	7.5	45.0	47.5	59.12
OPCB2	OP	CB	2	0.214	N	83	N	611	0.198	6.1	7.00	5.80	10.0	42.5	47.5	54.57
OPCB3	OP	CB	3	0.239	N	105	N	576	0.123	4.8	7.05	5.90	7.5	42.5	50.0	59.12

KANSAS CITY PLANT BIOASSAY DATA

SEDIMENT DESCRIPTIVE DATA

SAMPLEID	SEDIMENT	GRASS	REP	HN03_CD	HN03_K	HN03_ZN	HN03_TP	TKN	DTPA_CD	DTPA_ZN	WET_PH	DRY_PH	SAND	CLAY	SILT	CAC03
OPCE1	OP	CE	1	0.284	N	127	N	621	0.138	5.0	7.00	5.90	7.5	42.5	50.0	45.48
OPCE2	OP	CE	2	0.199	N	96	N	417	0.143	5.7	7.00	5.90	7.5	42.5	50.0	45.48
OPCE3	OP	CE	3	0.259	N	128	N	565	0.148	5.7	7.00	5.85	7.5	42.5	50.0	50.02
OPKB1	OP	KB	1	0.294	N	120	N	456	0.143	5.6	7.00	5.85	10.0	42.5	47.5	68.22
OPKB2	OP	KB	2	0.264	N	128	N	576	0.138	6.3	7.10	5.80	7.5	42.5	50.0	54.57
OPKB3	OP	KB	3	0.279	N	116	N	456	0.123	5.5	7.05	5.85	7.5	42.5	50.0	63.67
OPRF1	OP	RF	1	0.359	N	124	N	688	0.198	5.6	7.00	5.85	7.5	42.5	50.0	59.12
OPRF2	OP	RF	2	0.329	N	118	N	644	0.198	5.8	7.00	5.85	12.5	42.5	45.0	77.31
OPRF3	OP	RF	3	0.264	N	125	N	655	0.198	5.6	7.10	5.80	12.5	42.5	45.0	59.12
OPTF1	OP	TF	1	0.299	N	123	N	694	0.248	5.6	7.05	5.85	12.5	42.5	45.0	50.00
OPTF2	OP	TF	2	0.214	N	99	N	633	0.233	5.4	7.10	5.90	12.5	42.5	45.0	72.76
OPTF3	OP	TF	3	0.279	N	132	N	628	0.263	5.8	7.05	5.80	7.5	45.0	47.5	54.57
R1CB1	R1	CB	1	3.596	504	232	403	104	0.383	53.2	8.00	7.80	82.5	7.5	10.0	10.09
R1CB2	R1	CB	2	4.347	904	241	434	101	0.408	64.7	8.00	8.00	85.0	7.5	7.5	7.50
R1CB3	R1	CB	3	5.500	524	242	803	144	0.358	55.7	8.15	8.10	82.5	7.5	10.0	8.09
R1KB1	R1	KB	1	4.698	554	195	426	459	0.398	54.7	8.10	8.10	82.5	7.5	10.0	8.14
R1KB2	R1	KB	2	3.746	744	217	449	127	0.358	54.7	8.15	8.10	82.5	7.5	10.0	7.91
R1KB3	R1	KB	3	3.496	604	381	429	92	0.338	59.2	8.15	8.10	82.5	7.5	10.0	8.95
R1RF1	R1	RF	1	5.399	599	379	587	106	0.428	60.7	8.00	8.00	75.0	10.0	15.0	7.82
R1RF2	R1	RF	2	2.995	654	224	378	115	0.383	56.2	8.00	8.00	77.5	12.5	10.0	9.86
R1RF3	R1	RF	3	4.548	719	244	471	81	0.403	61.7	7.95	8.00	77.5	12.5	10.0	9.86
R1TF1	R1	TF	1	3.946	639	256	622	589	0.603	119.2	8.00	8.00	77.5	5.0	17.5	10.77
R1TF2	R1	TF	2	3.145	634	223	440	106	0.398	54.7	8.10	8.05	77.5	5.0	17.5	17.10
R1TF3	R1	TF	3	3.395	402	197	409	113	0.598	125.2	8.15	8.05	85.0	5.0	10.0	12.56
R2CB1	R2	CB	1	7.854	124	362	214	83	0.723	101.2	8.10	7.50	95.0	0.0	5.0	6.76
R2CB2	R2	CB	2	5.249	230	255	267	32	0.503	104.7	8.10	7.50	95.0	0.0	5.0	4.77
R2CB3	R2	CB	3	7.053	227	54	258	94	0.573	104.7	8.15	7.40	95.0	0.0	5.0	7.02

KANSAS CITY PLANT BIOASSAY DATA

SEDIMENT DESCRIPTIVE DATA

SAMPLEID	SEDIMENT	GRASS	REP	HN03_CD	HN03_K	HN03_ZN	HN03_TP	TKN	DTPA_CD	DTPA_ZN	WET_PH	DRY_PH	SAND	CLAY	SILT	CAC03
R2KB1	R2	KB	1	5.099	177	321	256	171	0.628	126.2	8.10	7.45	95.0	0.0	5.0	4.46
R2KB2	R2	KB	2	4.648	160	229	284	100	0.513	105.7	8.10	7.40	97.5	0.0	2.5	6.59
R2KB3	R2	KB	3	5.449	168	230	259	132	0.633	110.2	8.10	7.50	97.5	0.0	2.5	7.23
R2RF1	R2	RF	1	5.049	262	365	252	65	0.398	77.7	8.10	7.45	100.0	0.0	0.0	4.72
R2RF2	R2	RF	2	5.850	170	309	226	120	0.408	78.7	8.15	7.50	97.5	0.0	2.5	5.86
R2RF3	R2	RF	3	4.347	143	288	212	121	0.433	84.7	8.10	7.50	97.5	0.0	2.5	6.54
R2TF1	R2	TF	1	2.694	113	179	103	25	0.458	80.2	8.00	7.45	97.5	2.5	0.0	3.41
R2TF2	R2	TF	2	3.295	116	180	166	42	0.478	88.7	8.05	7.40	97.5	2.5	0.0	8.81
R2TF3	R2	TF	3	4.297	195	256	175	96	0.548	112.7	8.00	7.50	97.5	2.5	0.0	6.32

KANSAS CITY PLANT BIOASSAY DATA

WATER EXTRACTABLE DATA

COLUMN	DATA
SAMPLEID	SEDIMENT, REP
SEDIMENT	SEDIMENT LOCATION
REP	REPLICATE NUMBER
WATER_CD	WATER EXTRACTABLE CADMIUM (PPM, 1 TO 4)
WATER_ZN	WATER EXTRACTABLE ZINC (PPM, 1 TO 4)

KANSAS CITY PLANT BIOASSAY DATA

WATER EXTRACTABLE DATA

SAMPLEID	SEDIMENT	REP	WATER_CD	WATER_ZN
DS1	DS	1	0.0016	0.020
DS2	DS	2	0.0018	0.019
DS3	DS	3	0.0015	0.021
NB1	NB	1	0.0005	0.013
NB2	NB	2	0.0005	0.014
NB3	NB	3	0.0005	0.016
OP1	OP	1	0.0016	0.114
OP2	OP	2	0.0012	0.107
OP3	OP	3	0.0013	0.107
R11	R1	1	0.0012	0.012
R12	R1	2	0.0010	0.011
R13	R1	3	0.0009	0.010
R21	R2	1	0.0004	0.007
R22	R2	2	0.0003	0.007
R23	R2	3	0.0003	B

KANSAS CITY PLANT BIOASSAY DATA

SEDIMENT SULFUR DATA

COLUMN	DATA
SEDIMENT	SEDIMENT LOCATION
TOTAL_S	SEDIMENT TOTAL SULFUR (MG/KG)
SULFIDE	SEDIMENT SULFIDE (MG/KG)
SULFATE	SEDIMENT SULFATE (MG/KG)

KANSAS CITY PLANT BIOASSAY DATA

SEDIMENT SULFUR DATA

SEDIMENT	TOTAL_S	SULFIDE	SULFATE
DS	250	-10	-33
NB	320	-10	-33
OP	420	-10	128
R1	1010	73	672
R2	950	52	512

KANSAS CITY PLANT BIOASSAY DATA

PLANT BIOMASS DATA

COLUMN	DATA
SAMPLEID	SEDIMENT,GRASS,TREATMENT,REP
SEDIMENT	SEDIMENT LOCATION
GRASS	GRASS SPECIES
TREATMNT	"F"ERTILIZED OR "U"NFERTILIZED
REP	REPLICATE NUMBER
LEAVES	PLANT LEAF BIOMASS (G,ODW)
STEMS	PLANT STEM BIOMASS (G,ODW)
SEEDS	PLANT SEED BIOMASS (G,ODW)
DEAD	PLANT DEAD MATERIAL (G)
TOTAL	PLANT TOTAL BIOMASS (G,ODW)

KANSAS CITY PLANT BIOASSAY DATA

PLANT BIOMASS DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	LEAVES	STEMS	SEEDS	DEAD	TOTAL
DSCBF1	DS	CB	F	1	0.000	0.000	0.000	0.000	0.000
DSCBF2	DS	CB	F	2	0.000	0.000	0.000	0.000	0.000
DSCBF3	DS	CB	F	3	5.849	0.000	0.000	0.000	5.849
DSCBU1	DS	CB	U	1	4.956	0.000	0.000	0.000	4.956
DSCBU2	DS	CB	U	2	0.490	0.000	0.000	0.000	0.490
DSCBU3	DS	CB	U	3	1.783	0.000	0.000	0.000	1.783
DSCEF1	DS	CE	F	1	6.915	2.881	2.200	0.000	11.996
DSCEF2	DS	CE	F	2	6.874	3.394	3.284	0.000	13.552
DSCEF3	DS	CE	F	3	13.253	5.792	4.367	0.000	23.412
DSKBF1	DS	KB	F	1	0.000	0.000	0.000	0.000	0.000
DSKBF2	DS	KB	F	2	0.000	0.000	0.000	0.000	0.000
DSKBF3	DS	KB	F	3	0.003	0.000	0.000	0.000	0.003
DSKBU1	DS	KB	U	1	0.000	0.000	0.000	0.000	0.000
DSKBU2	DS	KB	U	2	0.062	0.000	0.000	0.000	0.062
DSKBU3	DS	KB	U	3	0.001	0.000	0.000	0.000	0.001
DSRFF1	DS	RF	F	1	0.005	0.000	0.000	0.000	0.005
DSRFF2	DS	RF	F	2	0.000	0.000	0.000	0.000	0.000
DSRFF3	DS	RF	F	3	0.002	0.000	0.000	0.000	0.002
DSRFU1	DS	RF	U	1	0.300	0.000	0.000	0.000	0.300
DSRFU2	DS	RF	U	2	0.100	0.000	0.000	0.000	0.100
DSRFU3	DS	RF	U	3	0.102	0.000	0.000	0.000	0.102
DSTFF1	DS	TF	F	1	1.492	0.311	0.000	0.000	1.803
DSTFF2	DS	TF	F	2	0.290	0.052	0.000	0.000	0.342
DSTFF3	DS	TF	F	3	0.019	0.000	0.000	0.000	0.019
DSTFU1	DS	TF	U	1	3.385	1.251	0.000	0.000	4.636
DSTFU2	DS	TF	U	2	1.327	0.065	0.000	0.000	1.392
DSTFU3	DS	TF	U	3	0.082	0.000	0.000	0.000	0.082

KANSAS CITY PLANT BIOASSAY DATA

PLANT BIOMASS DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	LEAVES	STEMS	SEEDS	DEAD	TOTAL
NBCBF1	NB	CB	F	1	40.160	0.000	0.000	0.000	40.160
NBCBF2	NB	CB	F	2	28.356	0.000	0.000	0.000	28.356
NBCBF3	NB	CB	F	3	30.220	0.000	0.000	0.000	30.220
NBCBU1	NB	CB	U	1	18.200	0.000	0.000	0.000	18.200
NBCBU2	NB	CB	U	2	14.780	0.000	0.000	0.000	14.780
NBCBU3	NB	CB	U	3	15.039	0.000	0.000	0.000	15.039
NBCEF1	NB	CE	F	1	10.867	4.153	1.385	4.649	21.054
NBCEF2	NB	CE	F	2	9.886	4.044	3.120	0.000	17.050
NBCEF3	NB	CE	F	3	13.900	3.962	1.533	4.042	23.437
NBKBF1	NB	KB	F	1	1.683	0.171	0.000	0.000	1.854
NBKBF2	NB	KB	F	2	0.073	0.000	0.000	0.000	0.073
NBKBF3	NB	KB	F	3	2.861	0.386	0.000	0.000	3.247
NBKBU1	NB	KB	U	1	2.614	0.362	0.000	0.000	2.976
NBKBU2	NB	KB	U	2	0.010	0.000	0.000	0.000	0.010
NBKBU3	NB	KB	U	3	0.992	0.055	0.000	0.000	1.047
NBRFF1	NB	RF	F	1	0.904	0.135	0.000	0.000	1.039
NBRFF2	NB	RF	F	2	0.160	0.020	0.000	0.000	0.180
NBRFF3	NB	RF	F	3	0.110	0.000	0.000	0.000	0.110
NBRFU1	NB	RF	U	1	1.136	0.000	0.000	0.000	1.136
NBRFU2	NB	RF	U	2	0.526	0.000	0.000	0.000	0.526
NBRFU3	NB	RF	U	3	0.043	0.000	0.000	0.000	0.043
NBTFF1	NB	TF	F	1	2.846	0.976	0.000	0.000	3.822
NBTFF2	NB	TF	F	2	0.990	0.215	0.000	0.000	1.205
NBTFF3	NB	TF	F	3	0.654	0.184	0.000	0.000	0.838
NBTFU1	NB	TF	U	1	1.729	0.084	0.000	0.000	1.813
NBTFU2	NB	TF	U	2	0.844	0.000	0.000	0.000	0.844
NBTFU3	NB	TF	U	3	2.150	0.090	0.000	0.000	2.240

KANSAS CITY PLANT BIOASSAY DATA

PLANT BIOMASS DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	LEAVES	STEMS	SEEDS	DEAD	TOTAL
OPCBF1	OP	CB	F	1	59.425	0.000	0.000	4.625	64.050
OPCBF2	OP	CB	F	2	157.028	0.000	0.000	1.283	158.311
OPCBF3	OP	CB	F	3	143.651	0.000	0.000	3.123	146.774
OPCEF1	OP	CE	F	1	18.715	7.413	2.907	0.000	29.035
OPCEF2	OP	CE	F	2	20.661	5.992	2.490	0.000	29.143
OPCEF3	OP	CE	F	3	22.822	5.300	0.835	0.000	28.957
OPKBF1	OP	KB	F	1	0.000	0.000	0.000	0.000	0.000
OPKBF2	OP	KB	F	2	0.000	0.000	0.000	0.000	0.000
OPKBF3	OP	KB	F	3	0.000	0.000	0.000	0.000	0.000
OPRFF1	OP	RF	F	1	0.000	0.000	0.000	0.000	0.000
OPRFF2	OP	RF	F	2	0.178	0.000	0.000	0.000	0.178
OPRFF3	OP	RF	F	3	0.063	0.000	0.000	0.000	0.063
OPTFF1	OP	TF	F	1	0.000	0.000	0.000	0.000	0.000
OPTFF2	OP	TF	F	2	0.290	0.075	0.000	0.075	0.440
OPTFF3	OP	TF	F	3	0.577	0.218	0.000	0.218	1.013
R1CBF1	R1	CB	F	1	41.876	0.000	0.000	0.000	41.876
R1CBF2	R1	CB	F	2	57.793	0.000	0.000	0.618	58.411
R1CBF3	R1	CB	F	3	47.550	0.000	0.000	0.000	47.550
R1CBU1	R1	CB	U	1	26.205	0.000	0.000	0.000	26.205
R1CBU2	R1	CB	U	2	23.181	0.000	0.000	0.000	23.181
R1CBU3	R1	CB	U	3	21.590	0.000	0.000	0.000	21.590
R1CEF1	R1	CE	F	1	15.740	5.959	2.975	0.000	24.674
R1CEF2	R1	CE	F	2	11.648	3.276	1.838	0.000	16.762
R1CEF3	R1	CE	F	3	9.300	3.349	2.299	0.000	14.948
R1KBF1	R1	KB	F	1	0.200	0.000	0.000	0.000	0.200
R1KBF2	R1	KB	F	2	0.314	0.043	0.000	0.000	0.357
R1KBF3	R1	KB	F	3	0.002	0.000	0.000	0.000	0.002

KANSAS CITY PLANT BIOASSAY DATA

PLANT BIOMASS DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	LEAVES	STEMS	SEEDS	DEAD	TOTAL
R1KBU1	R1	KB	U	1	1.095	0.000	0.000	0.000	1.095
R1KBU2	R1	KB	U	2	0.338	0.000	0.000	0.000	0.338
R1KBU3	R1	KB	U	3	0.215	0.000	0.000	0.000	0.215
R1RFF1	R1	RF	F	1	0.125	0.000	0.000	0.000	0.125
R1RFF2	R1	RF	F	2	0.003	0.000	0.000	0.000	0.003
R1RFF3	R1	RF	F	3	0.032	0.000	0.000	0.000	0.032
R1RFU1	R1	RF	U	1	0.427	0.000	0.000	0.000	0.427
R1RFU2	R1	RF	U	2	0.165	0.000	0.000	0.000	0.165
R1RFU3	R1	RF	U	3	0.271	0.000	0.000	0.000	0.271
R1TFF1	R1	TF	F	1	0.053	0.008	0.000	0.000	0.061
R1TFF2	R1	TF	F	2	0.138	0.020	0.000	0.000	0.158
R1TFF3	R1	TF	F	3	0.674	0.172	0.000	0.000	0.846
R1TFU1	R1	TF	U	1	0.886	0.042	0.000	0.000	0.928
R1TFU2	R1	TF	U	2	1.754	0.096	0.000	0.000	1.850
R1TFU3	R1	TF	U	3	0.153	0.000	0.000	0.000	0.153
R2CBF1	R2	CB	F	1	12.999	0.000	0.000	0.000	12.999
R2CBF2	R2	CB	F	2	13.082	0.000	0.000	0.000	13.082
R2CBF3	R2	CB	F	3	2.953	0.000	0.000	0.000	2.953
R2CBU1	R2	CB	U	1	0.328	0.000	0.000	0.000	0.328
R2CBU2	R2	CB	U	2	0.315	0.000	0.000	0.000	0.315
R2CBU3	R2	CB	U	3	0.263	0.000	0.000	0.000	0.263
R2CEF1	R2	CE	F	1	5.400	1.499	0.383	0.947	8.229
R2CEF2	R2	CE	F	2	5.219	1.952	0.986	1.480	9.637
R2CEF3	R2	CE	F	3	5.244	0.700	0.051	0.290	6.285
R2KBF1	R2	KB	F	1	0.000	0.000	0.000	0.000	0.000
R2KBF2	R2	KB	F	2	0.000	0.000	0.000	0.000	0.000
R2KBF3	R2	KB	F	3	0.100	0.000	0.000	0.000	0.100

KANSAS CITY PLANT BIOASSAY DATA

PLANT BIOMASS DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	LEAVES	STEMS	SEEDS	DEAD	TOTAL
R2KBU1	R2	KB	U	1	0.017	0.000	0.000	0.000	0.017
R2KBU2	R2	KB	U	2	0.074	0.000	0.000	0.000	0.074
R2KBU3	R2	KB	U	3	0.077	0.000	0.000	0.000	0.077
R2RFF1	R2	RF	F	1	0.030	0.000	0.000	0.000	0.030
R2RFF2	R2	RF	F	2	0.003	0.000	0.000	0.000	0.003
R2RFF3	R2	RF	F	3	0.192	0.020	0.000	0.000	0.212
R2RFU1	R2	RF	U	1	0.087	0.000	0.000	0.000	0.087
R2RFU2	R2	RF	U	2	0.038	0.000	0.000	0.000	0.038
R2RFU3	R2	RF	U	3	0.187	0.000	0.000	0.000	0.187
R2TFF1	R2	TF	F	1	0.274	0.062	0.000	0.000	0.336
R2TFF2	R2	TF	F	2	0.000	0.000	0.000	0.000	0.000
R2TFF3	R2	TF	F	3	0.211	0.026	0.000	0.000	0.237
R2TFU1	R2	TF	U	1	0.083	0.000	0.000	0.000	0.083
R2TFU2	R2	TF	U	2	0.207	0.000	0.000	0.000	0.207
R2TFU3	R2	TF	U	3	0.047	0.000	0.000	0.000	0.047

KANSAS CITY PLANT BIOASSAY DATA

LEAF CHEMISTRY DATA

COLUMN	DATA
SAMPLEID	SEDIMENT, GRASS, TREATMENT, REP
SEDIMENT	SEDIMENT LOCATION
GRASS	GRASS SPECIES
TREATMNT	"F" FERTILIZED OR "U" UNFERTILIZED
REP	REPLICATE NUMBER
WEIGHT	WEIGHT OF LEAF ANALYZED (G, ODW)
CADMIUM	LEAF CADMIUM CONC. (UG/G, ODW)
ZINC	LEAF ZINC CONC. (UG/G)

KANSAS CITY PLANT BIOASSAY DATA

LEAF CHEMISTRY DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
DSCBF1	DS	CB	F	1	G	G	G
DSCBF2	DS	CB	F	2	G	G	G
DSCBF3	DS	CB	F	3	1.998	0.295	19.5
DSCBU1	DS	CB	U	1	1.998	0.345	20.3
DSCBU2	DS	CB	U	2	0.473	0.378	24.8
DSCBU3	DS	CB	U	3	N	N	N
DSCEF1	DS	CE	F	1	1.995	0.761	143.0
DSCEF2	DS	CE	F	2	1.995	0.761	135.5
DSCEF3	DS	CE	F	3	1.995	0.786	93.6
DSKBF1	DS	KB	F	1	G	G	G
DSKBF2	DS	KB	F	2	G	G	G
DSKBF3	DS	KB	F	3	I	I	I
DSKBU1	DS	KB	U	1	G	G	G
DSKBU2	DS	KB	U	2	0.062	1.025	82.7
DSKBU3	DS	KB	U	3	I	I	I
DSRFF1	DS	RF	F	1	I	I	I
DSRFF2	DS	RF	F	2	I	I	I
DSRFF3	DS	RF	F	3	I	I	I
DSRFU1	DS	RF	U	1	0.250	0.434	25.3
DSRFU2	DS	RF	U	2	0.084	0.340	20.6
DSRFU3	DS	RF	U	3	0.087	0.788	B
DSTFF1	DS	TF	F	1	1.414	0.522	24.1
DSTFF2	DS	TF	F	2	0.232	0.856	20.4
DSTFF3	DS	TF	F	3	I	I	I
DSTFU1	DS	TF	U	1	1.998	1.045	34.3
DSTFU2	DS	TF	U	2	1.264	0.743	42.8
DSTFU3	DS	TF	U	3	N	N	N

KANSAS CITY PLANT BIOASSAY DATA

LEAF CHEMISTRY DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
NBCBF1	NB	CB	F	1	1.998	0.345	17.9
NBCBF2	NB	CB	F	2	1.998	0.420	22.9
NBCBF3	NB	CB	F	3	1.998	0.395	28.8
NBCBU1	NB	CB	U	1	N	N	N
NBCBU2	NB	CB	U	2	N	N	N
NBCBU3	NB	CB	U	3	N	N	N
NBCEF1	NB	CE	F	1	1.995	0.284	63.6
NBCEF2	NB	CE	F	2	1.995	0.861	105.9
NBCEF3	NB	CE	F	3	1.995	0.284	85.4
NBKBF1	NB	KB	F	1	1.624	0.670	96.8
NBKBF2	NB	KB	F	2	0.071	0.966	145.5
NBKBF3	NB	KB	F	3	1.998	0.720	80.9
NBKBU1	NB	KB	U	1	1.998	0.420	64.4
NBKBU2	NB	KB	U	2	I	I	I
NBKBU3	NB	KB	U	3	0.953	0.880	121.3
NBRFF1	NB	RF	F	1	0.844	0.330	40.7
NBRFF2	NB	RF	F	2	0.135	B	8.4
NBRFF3	NB	RF	F	3	0.104	B	1.2
NBRFU1	NB	RF	U	1	1.104	0.171	20.6
NBRFU2	NB	RF	U	2	N	N	N
NBRFU3	NB	RF	U	3	I	I	I
NBTFF1	NB	TF	F	1	1.998	0.445	44.4
NBTFF2	NB	TF	F	2	0.935	0.629	31.2
NBTFF3	NB	TF	F	3	0.623	1.025	74.4
NBTFU1	NB	TF	U	1	1.671	0.472	43.5
NBTFU2	NB	TF	U	2	N	N	N
NBTFU3	NB	TF	U	3	N	N	N

KANSAS CITY PLANT BIOASSAY DATA

LEAF CHEMISTRY DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
OPCBF1	OP	CB	F	1	1.998	N	N
OPCBF2	OP	CB	F	2	1.998	N	N
OPCBF3	OP	CB	F	3	1.998	N	N
OPCEF1	OP	CE	F	1	1.995	0.986	65.8
OPCEF2	OP	CE	F	2	1.995	0.585	51.0
OPCEF3	OP	CE	F	3	1.995	1.061	63.8
OPKBF1	OP	KB	F	1	N	N	N
OPKBF2	OP	KB	F	2	N	N	N
OPKBF3	OP	KB	F	3	N	N	N
OPRFF1	OP	RF	F	1	N	N	N
OPRFF2	OP	RF	F	2	0.161	N	N
OPRFF3	OP	RF	F	3	N	N	N
OPTFF1	OP	TF	F	1	N	N	N
OPTFF2	OP	TF	F	2	0.259	N	N
OPTFF3	OP	TF	F	3	0.537	N	N
R1CBF1	R1	CB	F	1	1.998	0.295	35.1
R1CBF2	R1	CB	F	2	1.998	0.245	33.3
R1CBF3	R1	CB	F	3	1.998	0.395	36.6
R1CBU1	R1	CB	U	1	N	N	N
R1CBU2	R1	CB	U	2	N	N	N
R1CBU3	R1	CB	U	3	N	N	N
R1CEF1	R1	CE	F	1	1.995	0.360	89.9
R1CEF2	R1	CE	F	2	1.995	0.585	95.4
R1CEF3	R1	CE	F	3	1.995	0.811	83.6
R1KBF1	R1	KB	F	1	0.179	0.914	160.5
R1KBF2	R1	KB	F	2	0.286	0.957	161.3
R1KBF3	R1	KB	F	3	I	I	I

KANSAS CITY PLANT BIOASSAY DATA

LEAF CHEMISTRY DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
R1KBUI	R1	KB	U	1	N	N	N
R1KBUI2	R1	KB	U	2	N	N	N
R1KBUI3	R1	KB	U	3	0.208	0.666	145.8
R1RFF1	R1	RF	F	1	0.128	0.419	33.8
R1RFF2	R1	RF	F	2	I	I	I
R1RFF3	R1	RF	F	3	I	I	I
R1RFU1	R1	RF	U	1	0.408	0.156	39.5
R1RFU2	R1	RF	U	2	0.145	0.266	60.2
R1RFU3	R1	RF	U	3	0.195	0.249	44.8
R1TFF1	R1	TF	F	1	0.057	0.501	132.1
R1TFF2	R1	TF	F	2	0.135	0.508	103.2
R1TFF3	R1	TF	F	3	0.640	0.998	150.2
R1TFU1	R1	TF	U	1	N	N	N
R1TFU2	R1	TF	U	2	N	N	N
R1TFU3	R1	TF	U	3	N	N	N
R2CBF1	R2	CB	F	1	1.998	0.795	57.9
R2CBF2	R2	CB	F	2	1.998	0.670	69.9
R2CBF3	R2	CB	F	3	1.998	0.670	82.1
R2CBUI	R2	CB	U	1	N	N	N
R2CBUI2	R2	CB	U	2	N	N	N
R2CBUI3	R2	CB	U	3	N	N	N
R2CEF1	R2	CE	F	1	1.995	0.811	71.1
R2CEF2	R2	CE	F	2	1.995	0.986	68.8
R2CEF3	R2	CE	F	3	1.995	0.961	60.1
R2KBF1	R2	KB	F	1	G	G	G
R2KBF2	R2	KB	F	3	G	G	G
R2KBF3	R2	KB	F	2	0.112	1.907	176.1

KANSAS CITY PLANT BIOASSAY DATA

LEAF CHEMISTRY DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
R2KBU1	R2	KB	U	1	I	I	I
R2KBU2	R2	KB	U	2	0.072	1.091	196.2
R2KBU3	R2	KB	U	3	N	N	N
R2RFF1	R2	RF	F	1	I	I	I
R2RFF2	R2	RF	F	2	I	I	I
R2RFF3	R2	RF	F	3	0.155	1.055	162.1
R2RFU1	R2	RF	U	1	0.077	0.241	43.2
R2RFU2	R2	RF	U	2	I	I	I
R2RFU3	R2	RF	U	3	N	N	N
R2TFF1	R2	TF	F	1	0.268	0.760	131.1
R2TFF2	R2	TF	F	2	G	G	G
R2TFF3	R2	TF	F	3	0.209	0.807	155.6
R2TFU1	R2	TF	U	1	N	N	N
R2TFU2	R2	TF	U	2	N	N	N
R2TFU3	R2	TF	U	3	I	I	I

KANSAS CITY PLANT BIOASSAY DATA

PLANT UPTAKE DATA

COLUMN	DATA
SAMPLEID	SEDIMENT, GRASS, TREATMENT, REP
SEDIMENT	SEDIMENT LOCATION
GRASS	GRASS SPECIES
TREATMNT	"F" FERTILIZED OR "U" UNFERTILIZED
REP	REPLICATE NUMBER
WEIGHT	WEIGHT OF LEAF ANALYZED (G, ODW)
CADMIUM	PLANT CADMIUM UPTAKE (UG)
ZINC	PLANT ZINC UPTAKE (UG)

KANSAS CITY PLANT BIOASSAY DATA

PLANT UPTAKE DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
DSCBF1	DS	CB	F	1	G	G	G
DSCBF2	DS	CB	F	2	G	G	G
DSCBF3	DS	CB	F	3	1.998	1.723	114.0
DSCBU1	DS	CB	U	1	1.998	1.708	100.5
DSCBU2	DS	CB	U	2	0.473	0.185	12.2
DSCBU3	DS	CB	U	3	N	N	N
DSCEF1	DS	CE	F	1	1.995	9.125	1715.7
DSCEF2	DS	CE	F	2	1.995	10.308	1836.3
DSCEF3	DS	CE	F	3	1.995	18.395	2192.5
DSKBF1	DS	KB	F	1	G	G	G
DSKBF2	DS	KB	F	2	G	G	G
DSKBF3	DS	KB	F	3	I	I	I
DSKBU1	DS	KB	U	1	G	G	G
DSKBU2	DS	KB	U	2	0.062	0.064	5.1
DSKBU3	DS	KB	U	3	I	I	I
DSRFF1	DS	RF	F	1	I	I	I
DSRFF2	DS	RF	F	2	I	I	I
DSRFF3	DS	RF	F	3	I	I	I
DSRFU1	DS	RF	U	1	0.250	0.130	7.6
DSRFU2	DS	RF	U	2	0.084	0.034	2.1
DSRFU3	DS	RF	U	3	0.087	0.080	B
DSTFF1	DS	TF	F	1	1.414	0.942	43.5
DSTFF2	DS	TF	F	2	0.232	0.293	7.0
DSTFF3	DS	TF	F	3	I	I	I
DSTFU1	DS	TF	U	1	1.998	4.846	159.2
DSTFU2	DS	TF	U	2	1.264	1.034	59.6
DSTFU3	DS	TF	U	3	N	N	N

KANSAS CITY PLANT BIOASSAY DATA

PLANT UPTAKE DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
NBCBF1	NB	CB	F	1	1.998	13.840	718.1
NBCBF2	NB	CB	F	2	1.998	11.901	649.0
NBCBF3	NB	CB	F	3	1.998	11.927	871.6
NBCBU1	NB	CB	U	1	N	N	N
NBCBU2	NB	CB	U	2	N	N	N
NBCBU3	NB	CB	U	3	N	N	N
NBCEF1	NB	CE	F	1	1.995	5.989	1338.4
NBCEF2	NB	CE	F	2	1.995	14.678	1806.1
NBCEF3	NB	CE	F	3	1.995	6.667	2001.0
NBKBF1	NB	KB	F	1	1.624	1.243	179.4
NBKBF2	NB	KB	F	2	0.071	0.071	10.6
NBKBF3	NB	KB	F	3	1.998	2.338	262.7
NBKBU1	NB	KB	U	1	1.998	1.249	191.6
NBKBU2	NB	KB	U	2	I	I	I
NBKBU3	NB	KB	U	3	0.953	0.921	127.0
NBRFF1	NB	RF	F	1	0.844	0.343	42.3
NBRFF2	NB	RF	F	2	0.135	B	1.5
NBRFF3	NB	RF	F	3	0.104	B	0.1
NBRFU1	NB	RF	U	1	1.104	0.194	23.4
NBRFU2	NB	RF	U	2	N	N	N
NBRFU3	NB	RF	U	3	I	I	I
NBTFF1	NB	TF	F	1	1.998	1.700	169.5
NBTFF2	NB	TF	F	2	0.935	0.759	37.5
NBTFF3	NB	TF	F	3	0.623	0.859	62.3
NBTFU1	NB	TF	U	1	1.671	0.856	78.8
NBTFU2	NB	TF	U	2	N	N	N
NBTFU3	NB	TF	U	3	N	N	N

KANSAS CITY PLANT BIOASSAY DATA

PLANT UPTAKE DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
OPCBF1	OP	CB	F	1	1.998	N	N
OPCBF2	OP	CB	F	2	1.998	N	N
OPCBF3	OP	CB	F	3	1.998	N	N
OPCEF1	OP	CE	F	1	1.995	28.635	1911.3
OPCEF2	OP	CE	F	2	1.995	17.055	1487.5
OPCEF3	OP	CE	F	3	1.995	30.735	1848.1
OPKBF1	OP	KB	F	1	N	N	N
OPKBF2	OP	KB	F	2	N	N	N
OPKBF3	OP	KB	F	3	N	N	N
OPRFF1	OP	RF	F	1	N	N	N
OPRFF2	OP	RF	F	2	0.161	N	N
OPRFF3	OP	RF	F	3	N	N	N
OPTFF1	OP	TF	F	1	N	N	N
OPTFF2	OP	TF	F	2	0.259	N	N
OPTFF3	OP	TF	F	3	0.537	N	N
R1CBF1	R1	CB	F	1	1.998	12.336	1469.8
R1CBF2	R1	CB	F	2	1.998	14.283	1947.9
R1CBF3	R1	CB	F	3	1.998	18.767	1740.4
R1CBU1	R1	CB	U	1	N	N	N
R1CBU2	R1	CB	U	2	N	N	N
R1CBU3	R1	CB	U	3	N	N	N
R1CEF1	R1	CE	F	1	1.995	8.874	2217.9
R1CEF2	R1	CE	F	2	1.995	9.809	1599.1
R1CEF3	R1	CE	F	3	1.995	12.119	1250.0
R1KBF1	R1	KB	F	1	0.179	0.183	32.1
R1KBF2	R1	KB	F	2	0.286	0.341	57.6
R1KBF3	R1	KB	F	3	I	I	I

KANSAS CITY PLANT BIOASSAY DATA

PLANT UPTAKE DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
R2KBUI	R2	KB	U	1	I	I	I
R2KBUI2	R2	KB	U	2	0.072	0.081	14.5
R2KBUI3	R2	KB	U	3	N	N	N
R2RFF1	R2	RF	F	1	I	I	I
R2RFF2	R2	RF	F	2	I	I	I
R2RFF3	R2	RF	F	3	0.155	0.224	34.4
R2RFU1	R2	RF	U	1	0.077	0.021	3.8
R2RFU2	R2	RF	U	2	I	I	I
R2RFU3	R2	RF	U	3	N	N	N
R2TFF1	R2	TF	F	1	0.268	0.255	44.0
R2TFF2	R2	TF	F	2	G	G	G
R2TFF3	R2	TF	F	3	0.209	0.191	36.9
R2TFU1	R2	TF	U	1	N	N	N
R2TFU2	R2	TF	U	2	N	N	N
R2TFU3	R2	TF	U	3	I	I	I

KANSAS CITY PLANT BIOASSAY DATA

PLANT UPTAKE DATA

SAMPLEID	SEDIMENT	GRASS	TREATMNT	REP	WEIGHT	CADMIUM	ZINC
R1KBU1	R1	KB	U	1	N	N	N
R1KBU2	R1	KB	U	2	N	N	N
R1KBU3	R1	KB	U	3	0.208	0.143	31.3
R1RFF1	R1	RF	F	1	0.128	0.052	4.2
R1RFF2	R1	RF	F	2	I	I	I
R1RFF3	R1	RF	F	3	I	I	I
R1RFU1	R1	RF	U	1	0.408	0.067	16.9
R1RFU2	R1	RF	U	2	0.145	0.044	9.9
R1RFU3	R1	RF	U	3	0.195	0.068	12.1
R1TFF1	R1	TF	F	1	0.057	0.031	8.1
R1TFF2	R1	TF	F	2	0.135	0.080	16.3
R1TFF3	R1	TF	F	3	0.640	0.844	127.1
R1TFU1	R1	TF	U	1	N	N	N
R1TFU2	R1	TF	U	2	N	N	N
R1TFU3	R1	TF	U	3	N	N	N
R2CBF1	R2	CB	F	1	1.998	10.335	752.3
R2CBF2	R2	CB	F	2	1.998	8.764	914.2
R2CBF3	R2	CB	F	3	1.998	1.978	242.6
R2CBU1	R2	CB	U	1	N	N	N
R2CBU2	R2	CB	U	2	N	N	N
R2CBU3	R2	CB	U	3	N	N	N
R2CEF1	R2	CE	F	1	1.995	6.672	585.0
R2CEF2	R2	CE	F	2	1.995	9.504	663.4
R2CEF3	R2	CE	F	3	1.995	6.041	377.5
R2KBF1	R2	KB	F	1	G	G	G
R2KBF2	R2	KB	F	3	G	G	G
R2KBF3	R2	KB	F	2	0.112	0.191	17.6