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Environmental Effects of Dredging Technical Notes

HEAVY METAL UPTAKE BY AGRONOMIC CROPS AND *CYPERUS ESCULENTUS* GROWN ON OXIDIZED AND REDUCED SOILS CONTAMINATED WITH METAL-MINING WASTES

PURPOSE: This note expands the scope and utility of the Waterways Experiment Station (WES) plant bioassay procedure by using *Cyperus esculentus* (yellow nutsedge) as an index plant to link an existing agronomic data base to that of the WES data base. Relating contaminant uptake and mobility by the index plant grown on dredged material to that of an existing agricultural data base may show that levels of contaminant uptake by plants and subsequent mobility into the food web from dredged material may be compared to what is normally acceptable in agricultural products. Therefore, contaminant uptake and mobility may not be as harmful to the environment as often projected (i.e., absence of "unacceptable adverse effect").

This technical note is a synopsis of a contract report prepared under the Toxic Substances Bioaccumulation by Plants work unit in the Long-Term Effects of Dredging Operations Program. Dr. Brian E. Davies and Ms. Nicola J. Houghton of the University College of Wales, Aberystwyth, Great Britain, conducted the study.

BACKGROUND: WES has developed a plant bioassay procedure using the freshwater plant *C. esculentus* to evaluate the mobility of contaminants from dredged material into the environment. The utility and scope of the procedure are being expanded and evaluated by using *C. esculentus* as an index plant to link several large agronomic data bases. One of these large data bases describes vegetable crop production on metal-contaminated mining wastes in the United Kingdom. The plant bioassay procedure was tested by researchers from the University College of Wales, Aberystwyth, Great Britain. Specific objectives of this study were to implement the plant bioassay procedure using metal-contaminated mining wastes from old mining sites and to relate the resulting plant uptake data to the Welsh data base.

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Approach

Contaminated soils were collected from areas in Wales and western England where base metals had been mined in the nineteenth century. Two of these areas were near Liverpool, two near Aberystwyth, and one near Bristol. Each soil contained high levels of one or more of the following heavy metals: lead (Pb), zinc (Zn), copper (Cu), and cadmium (Cd). A silty soil from the WES reservation served as a reference soil. Heavy metal uptake from each of the soils by the WES index plant, *C. esculentus*, was investigated in a controlled greenhouse environment under reduced (flooded) and oxidized (upland) conditions. The effect of liming the soils on heavy metal uptake by the agronomic crops was investigated since increased soil pH was necessary for crop growth. The agronomic crops included lettuce (*Lactuca sativa* var. Paris White), radish (*Raphanus sativus* L. var. Webb's French Breakfast), wheat (*Triticum aestivum* var. Timmo), red fescue (*Festuca rubra* var. Merlin), and Italian ryegrass (*Lolium multiflorum* S23). Each crop was grown in each of the contaminated soils until full vegetative growth had been reached, at which time the crops were harvested. Each treatment was replicated three times.

The plants were analyzed for acid (HNO_3) extractable Cd, Cu, Zn, and Pb. The soils were analyzed for HNO_3, diethylene triamine pentaacetic acid (DTPA), and ethylene diamine tetraacetic acid (EDTA) extractable Cd, Cu, Zn, and Pb. DTPA had been used extensively in the WES plant bioassay procedure, while EDTA had been used in Wales to estimate mobility of heavy metals. Extracting the same soils with both extracts provided a link between the WES and the Welsh soil-extraction procedures.

Results

DTPA and EDTA extractable heavy metal levels were higher from the aerobic soils than from the flooded soils. Folsom, Lee, and Bates (1981) had found the same result with DTPA when flooded sediments were drained and allowed to oxidize. They attributed this behavior to oxidation of heavy metal-organic matter complexes into simpler more soluble and more mobile forms. Increased mobility subsequently increased plant availability of the metals. However, the soils used in the present study were oxidized prior to flooding. When an oxidized soil is flooded, the reduction process converts inorganic sulfates into sulfides and results in the formation of less soluble heavy metal sulfides (Gambrell et al. 1977). Reduced solubility of the heavy metals in the flooded soils is reflected in reduced heavy metal concentrations in both DTPA and EDTA extractions and implies reduced plant availability of heavy metals. However, when heavy metal levels obtained by DTPA extraction were correlated with plant uptake levels, Cd was the only metal significantly less available from flooded soil.

Significant positive correlation was found between DTPA extractable Cd and plant uptake of Cd by agronomic crops. DTPA extractable Cd accounted for over 92 percent of the variability (r^2 = 0.92) of Cd in tissue of radish leaves, radish bulbs, lettuce, and *C. esculentus*. DTPA extractable Cd accounted for 81 percent of the variability in tissue of Italian ryegrass. DTPA extractable Cd accounted for only 61 percent of tissue Cd in red fescue, while that of wheat was less than 45 percent. The correlation between DTPA extractable Cu and Zn and plant uptake was positive but was not as significant as for Cd. DTPA extractable Cu, however, accounted for 84 percent of the variability in *C. esculentus*, while DTPA extractable Zn accounted for only 31 percent. The correlation between DTPA extractable Pb and plant uptake was marginal (generally, $r^2 < 0.50$). DTPA extractable Pb accounted for only 40 percent of tissue Pb in *C. esculentus*.

Significant positive correlations were found (Figures 1 and 2) between *C. esculentus* and agronomic crop heavy metal uptake and established the link between the Welsh and WES data bases. The correlations varied between metals and plant species. Cadmium and zinc correlation between *C. esculentus* and agronomic crops were not as strong, however, as those found by van Driel, Smilde, and van Luit (1985).

Reduced uptake and subsequent reduced correlation between plant heavy metals in agronomic crops and *C. esculentus* could have resulted from liming the soils. Liming was necessary to support plant growth of the agricultural crops. Liming did not affect *C. esculentus*. Increased crop growth may have masked increased metal uptake since increased plant dry matter may have resulted in a dilution effect (i.e., because the increased plant growth was not proportional to increased metal uptake). When these same crops were grown on contaminated sediments (pH of 7.0 or greater), highly significant correlations between the heavy metal status of *C. esculentus* and the crops were found (van Driel, Smilde, and van Luit 1985). Bingham et al. (1979) found that Cd

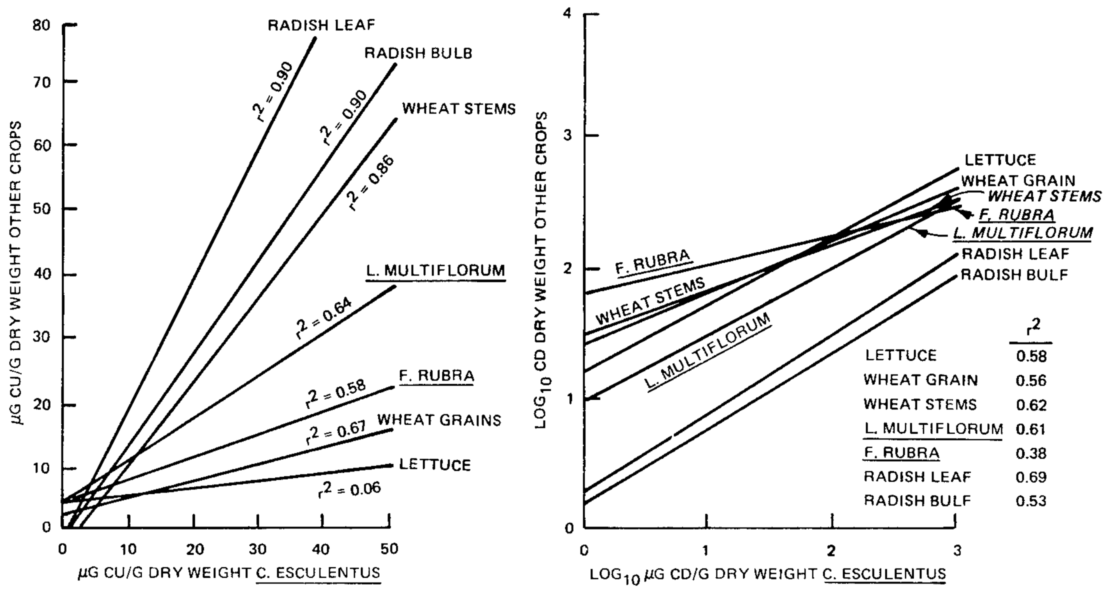

Figure 1. Correlation between heavy metal uptake (Cu and Cd) by *C. esculentus* and other agronomic crops

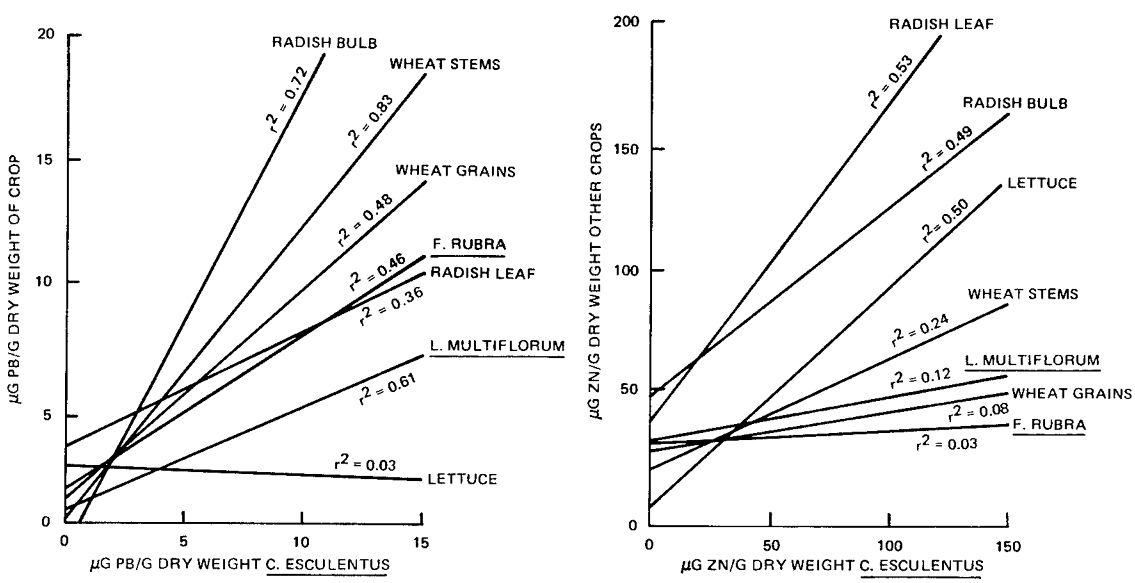

Figure 2. Correlation between heavy metal uptake (Pb and Zn) by *C. esculentus* and other agronomic crops

was phytotoxic (reduced plant growth) even in limed soils and also noted that liming reduced the correlation between DTPA extractable Cd and Cd uptake by wheat grain. Apparently, liming of contaminated soils can increase plant growth and obscure the relationship between increased plant growth and increased metal uptake. Liming also reduced correlation between DTPA extractable heavy metals and plant uptake of heavy metals.

In conclusion, the plant bioassay procedure was implemented using metal-contaminated mining wastes from old mining sites. The procedure was shown to be appropriate for evaluating contaminant mobility. Resulting plant uptake data can be used to link the Welsh agronomic and WES *C. esculentus* data bases.

References

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