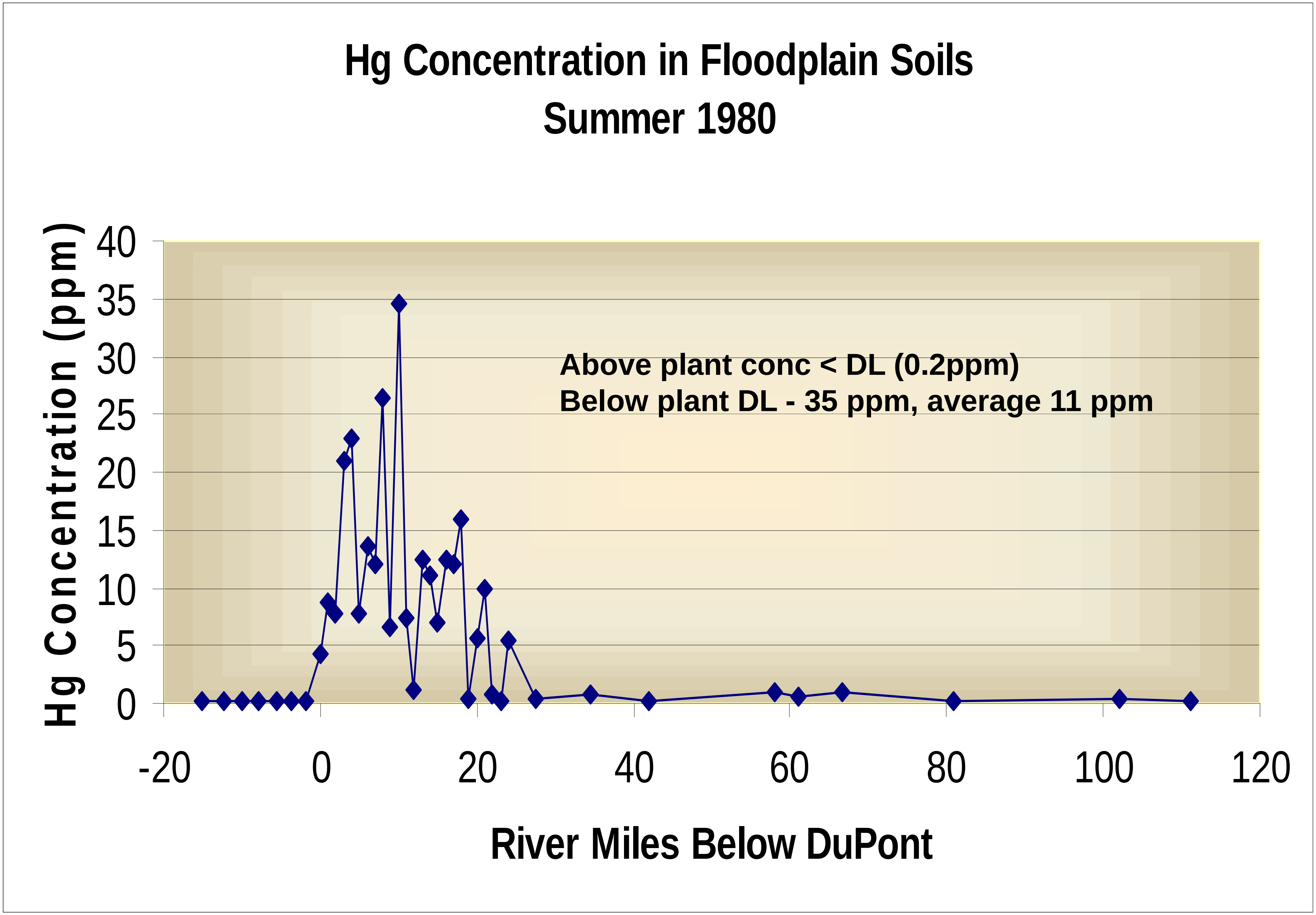
# Mercury in Soils: Transfer through the Food Chain Literature Review

**4/23/02**

# Original Information Review

- **Mercury contamination of the South, South Fork Shenandoah and Shenandoah Rivers. State Water Control Board, Basic Data Bulletin 47, March 1980.**
- **Mercury contamination of the flood plains of the South and South Fork Shenandoah Rivers. Virginia State Water Control Board, Basic Data Bulletin 48, May 1981.**
- **Engineering feasibility study of rehabilitating the South River and South Fork Shenandoah River. Vol I., Lawler, Matusky & Skelly, 1981.**
- **Engineering feasibility study of rehabilitating the South River and South Fork Shenandoah River. Vol II., Lawler, Matusky & Skelly, 1982.**
- **Cooking, et al, 1991. Water, Air, and Soil Pollution 57-58: 159-170**
- **USEPA (1995) Guide to the Biosolids Risk Assessments for the EPA Part 503 Rule, EPA/832-B-93-005**
- **NAS (1996) Use of Reclaimed Water and Sludge in Food Production**



Hg Concentration in Floodplain Soils
Summer 1980
Hg Concentration (ppm)
40
35
30
25
20
15
10
5
0
-20
0
20
40
60
80
100
120
River Miles Below DuPont
Above plant conc < DL (0.2ppm)
Below plant DL - 35 ppm, average 11 ppm

# Data suggests...

- Greater  90% of Hg believed to be in floodplain soils
- Materials in floodplain are not available
- Number of uncertainties, e.g., are there unacceptable exposures
- Should we consider a field study…
  - Initial step..further review the literature

# Literature Review - Goals

- Determine knowledge base on the topic
  - –relative to information for sludge
- Assess validity of LMS conclusions
  - – Hg in floodplains are not available

# Current review

- **Internet-wide search**
- **100+ articles**
- **Focused on**
  - **Hg Study Report to Congress, Volume III:Fate and Transport of Mercury in the Environment EPA-452/R-97-005 (12/97)**
  - **U.S. Department of Energy (1998) Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants**
  - **Both exhaustive reviews of the literature on the topic**
- **Personal communication with DuPont Scientists**
- **Personal communication with JMU**

# Hg Study Report to Congress 97

## Mercury in Soils

- Soil conditions (e.g., pH, temperature and soil humic content) favor
  - formation of inorganic Hg(II) compounds (e.g., HgCl , Hg(OH)
  - inorganic Hg(II) compounds complexed with organic molecules
- Inorganic Hg(II) compounds are quite soluble (theoretically mobile)
- However, they form complexes with soil organic matter (mainly fulvic and humic acids) and mineral colloids; (former dominates)
- Complexing behavior greatly limits the mobility of mercury in soil.

# Hg Study Report to Congress 97

## Mercury in Soils (cont.)

- Much of the mercury in soil is bound to bulk organic matter
  - elution in runoff only by attachment to suspended soil/ humus.
  - Some Hg(II) does sorb to dissolvable organic ligands and other forms of dissolved organic carbon (DOC)
  - may then partition to runoff in the dissolved phase**.**
- **Methylmercury can be formed by various microbial processes**
  - Approximately 1-3% of the total mercury in surface soil is methylmercury, largely bound to organic matter.

# Hg Study Report to Congress 97

## Plant and Animal Uptake of Mercury

- Hg(II) and methylmercury complexes in soil theoretically available for plant uptake
  - potentially resulting in transfer through the terrestrial food chain.
- Reality: plant uptake from ordinary soils, especially to above-ground parts of plants, appears to be insignificant
  - confirmed in several studies
  - most of Hg in plants is from air deposition

# Hg Study Report to Congress 97

## Plant and Animal Uptake of Mercury (cont)

- Plants can also produce mercury methylation
  - so methylmercury in plants may not originate from root uptake.
- A few studies have reported plant uptake from soil
  - Typically from heavily polluted soils near Chlor-alkali plants where the formation of Cl complexes can increase Hg(II) movement

# Hg Study Report to Congress 97

<u>Plant and Animal Uptake of Mercury (cont)</u>

- Overall, mercury concentrations in plants, even those whose main uptake appears to be from the air, are small
- Accordingly, livestock typically accumulates little mercury from foraging or silage/grain consumption, and mercury content in meat is low
- *Terrestrial pathway not expected to be significant in comparison to the consumption of fish by humans and wildlife*

# Hg Study Report to Congress 97

## Plant - Soil BCF (ratio of plant conc to soil conc.)

| Crop | $Hg^{2+}$ | | Methylmercury | |
|---|---|---|---|---|
| | **Default Value** | **Distribution** | **Default Value** | **Distribution** |
| Leafy vegetables | 0 | None | 0 | None |
| Legume vegetables | 0.015 | U(0.00026, 0.157) | 0.031 | U(0.0, 0.090) |
| Fruiting vegetables | 0.018 | U(0.007,0.059) | 0.024 | U(0.0,0.11) |
| Rooting vegetables | 0.036 | U(0.011, 0.073) | 0.099 | U(0.013,0.29) |
| Grains and cereals | 0.0093 | U(0.0024,0.057) | 0.019[a] | U(0.0048,0.11)[a] |
| Forage | 0 | None | 0 | None |
| Fruits | 0.018 | U(0.007-0.059) | 0.024 | U(0.0,0.11) |
| Potatoes | 0.1 | U(0.05,0.2) | 0.2[a] | U(0.1,0.4)[a] |
| Silage | 0 | None | 0 | None |

[a] $Hg^{2+}$ values multiplied by 2

# Hg Study Report to Congress 97

**Soil-to-Plant Transfer Coefficients for Mercury**
**(from Cappon, 1987 and Cappon, 1981)**

| Crop | 1987 Values | | 1981 Values | |
|---|---|---|---|---|
| | $Hg^{2+}$ | Methylmercury | $Hg^{2+}$ | Methylmercury |
| | *Rooting Vegetables* | | | |
| Beet | .055 | .227 | .017 | .11 |
| Carrot | .026 | .118 | .014 | .048 |
| Onion, Yellow | .073 | .288 | .053 | .042 |
| Onion, Spanish | - | - | .047 | .030 |
| Red Radish | .056 | .092 | .018 | .066 |
| White Radish | - | - | .011 | .060 |
| Turnip | .026 | .013 | - | - |
| | *Fruiting Vegetables* | | | |
| Cucumber, slicing | - | - | .015 | 0 |
| Cucumber, pickle | .007 | 0 | .015 | .006 |
| Pepper | .019 | .022 | .016 | .042 |
| Zucchini | .021 | 0 | .014 | .018 |
| Summer Squash | - | - | .007 | 0 |
| Acorn Squash | - | - | .016 | .012 |
| Spaghetti Squash | - | - | .016 | .024 |
| Pumpkin | - | - | .008 | .006 |
| Tomato | .059 | .105 | .020 | .072 |
| | *Legumes* | | | |
| Green Bush Beans | .011 | 0 | .014 | .020 |
| Yellow Bush Beans | - | - | .017 | .015 |
| Lima Beans | - | - | .017 | .090 |

# Hg Study Report to Congress 97

**Other Values for Soil-to-Plant Transfer Coefficients for $Hg^{2+}$**

| Crop | Values | References |
|---|---|---|
| Legume vegetables | 0.157-1.79, 0.00026-0.0003, 0.0005, 0.003-0.03 | Lenka et al. (1992), Somu et al. (1985), John (1972), Belcher and Travis (1989). |
| Fruiting vegetables | 0.013-0.33, 0.127-1.36, 0.0078-0.028 | Temple and Linzon (1977), Lenka et al. (1992), Belcher and Travis (1989). |
| Rooting vegetables | 0.09-0.33, 0.090-0.149, 0.0065-0.013, 0.05-0.2, 1.6-1.9 | Temple and Linzon (1977), Lenka et al. (1992), John (1972), Belcher and Travis (1989), Mosbaek (1988) |
| Grains and cereals | 0.0024-0.0093, 0.0033, 0.00038-0.057 | Somu et al. (1985), John (1972), Belcher and Travis (1989). |
| Fruits | 0.0078-0.028 | Belcher and Travis (1989). |
| Potatoes | 0.05-0.2 | Belcher and Travis (1989). |

# **U.S. Department of Energy** (1998)

- **Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants**
- **Same general conclusions**
- **145 values compiled**
  - **Geometric mean for soil-plant transfer factor: 0.344**

# Personal Communications

## DuPont CR&D

- **Mercury Report to Congress..state of the science**
- **Recent efforts..focused on evaluating phytoremediation for Hg removal**
- **Not successful**

**1976 “Sludge” Studies**

- **No difference between levels in tissues of cow raised on control pasture vs. sludge amended.**

# Personal Communications

## JMU Studies

- **Evaluation of terrestrial floodplain ecosystem, Waynesboro as example, growing seasons 1983-85**
  - **Soil conc range 11- 84ppm, Average in test area 5 - 25 ppm**
  - **Hg widely distributed - found in greater levels in roots than leaves, detritus eaters than grazers**
  - **Flooding/river sediment an issue for terrestrial ecosystem**

# Personal Communications

## JMU Studies (cont)

- Follow-up
  - No significant activity since original publications
  - Of interest…
    - soil profile showed only surface contamination
    - surface soils contamination “shifted”, could not be reproduced
    - air deposition on leaves same “up-gradient” and “down-gradient” of Waynesboro

# Conclusions

- Significant body of literature to support that materials are not readily available …except by physical movement
- Air deposition onto leaves likely bigger concern than uptake from soil
- Continue with phased approach to address issue...

# Phased Approach to Reducing Uncertainty

- Are there unacceptable exposures to Hg from floodplain soils?
  - Develop exposure scenarios based on landuse
    - Identify potential exposure pathways
  - Definitive landuse survey for the area
    - Focus on South River
    - 100 & 500 year floodplain, magnitude of flooding
    - Agricultural vs residential activity
  - Re-visit field study