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UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
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SECOND AUTUMN WORKSHOP ON MATHEMATICAL ECOLOGY

(2 - 20 November 1992)

"Water Quality Modeling and Government Regulations"

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These are preliminary lecture notes, intended only for distribution to participants.

Water Quality Modeling and Government Regulations

Introduction

1. Clean Water Act - 1972

    Fishable - Swimable Waters

    Technology based approach - Secondary Treatment or its equivalent

2. Amendments - 1978

    Water Quality Based Approach

        Receiving water concentrations

        Water Quality Criteria

3. Presently being considered

    Sediment Quality Based Approach

        Sediment concentrations - observed and computed

        Sediment Quality Criteria

Water Quality Criteria

1. Acute Toxicity

   Acute toxicity = 96hr LC50 = Concentration that causes 50% mortality in 96hr.

   5th percentile of the acute toxicities for all species tested / 2 = Final Acute Value (FAV)

2. Chronic Toxicity

   Chronic toxicity - long term, life or partial life cycle tests. Acute to chronic ratio

   Median acute to chronic ratio = ACR

3. Chronic Criteria

   Final Chronic Value = Final Acute Value / Median Acute to Chronic Ratio

   FCV = FAV / ACR

SEDIMENT QUALITY CRITERIA

*** What are they?**

Chemical concentration in a sediment that is protective of aquatic life.

Applies to all sediments.

Analogous to Water Quality Criteria.

*** What units should be used?**

Traditional units for sediments:

ug chemical / g dry weight sediment

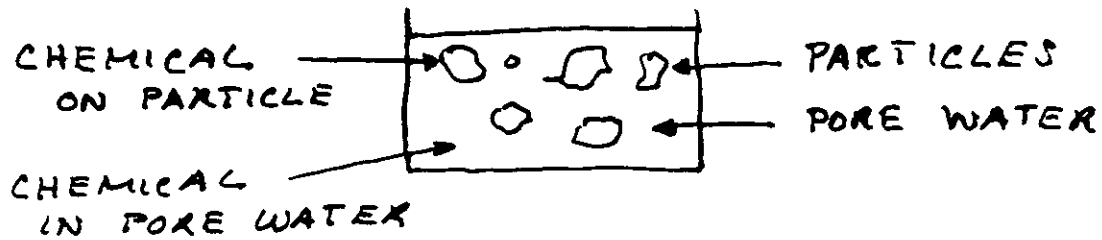
What about:

ug chemical / g WET weight sediment

The issue is:

What concentration correlates to biological effects?

DEFINITIONS : SEDIMENTS



PARTICLE CONCENTRATION

m = g particles / L sediment (~ 500 g/L)

POROSITY

ϕ = VOLUME PORE WATER / VOLUME SEDIMENT

~ 50 - 90 %

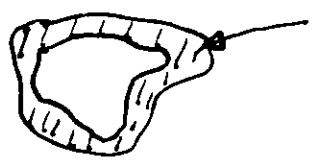
CHEMICAL CONCENTRATION

1. BULK WET WEIGHT $C_{BULK} = \frac{\text{mg TOTAL CHEMICAL}}{\text{g TOTAL SEDIMENT}}$

2. DRY WEIGHT (PARTICULATE) $C_S = \frac{\text{mg TOTAL CHEMICAL}}{\text{g PARTICLES}}$

3. PORE WATER (DISSOLVED) $C_d = \frac{\text{mg DISSOLVED CHEMICAL}}{\text{L PORE WATER}}$

PARTICLE COMPOSITION



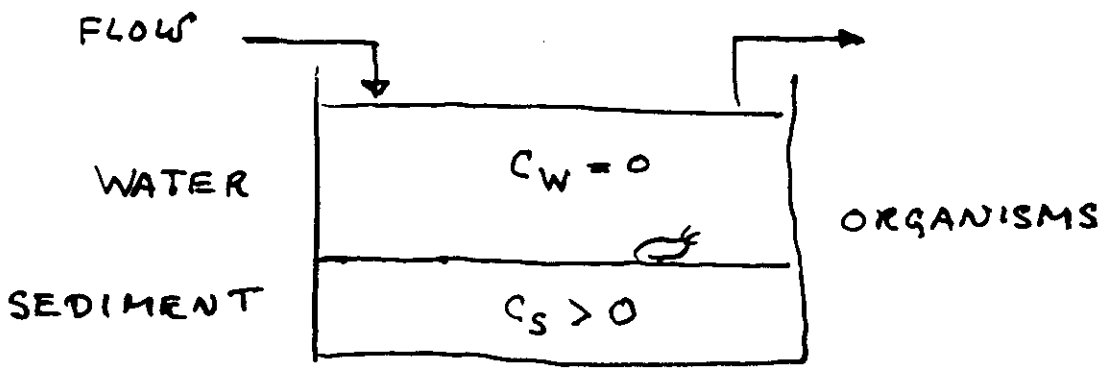
ORGANIC CARBON (HUMUS)

FRACTION ORGANIC CARBON $f_{oc} = \frac{\text{g ORGANIC C}}{\text{g PARTICLE}}$

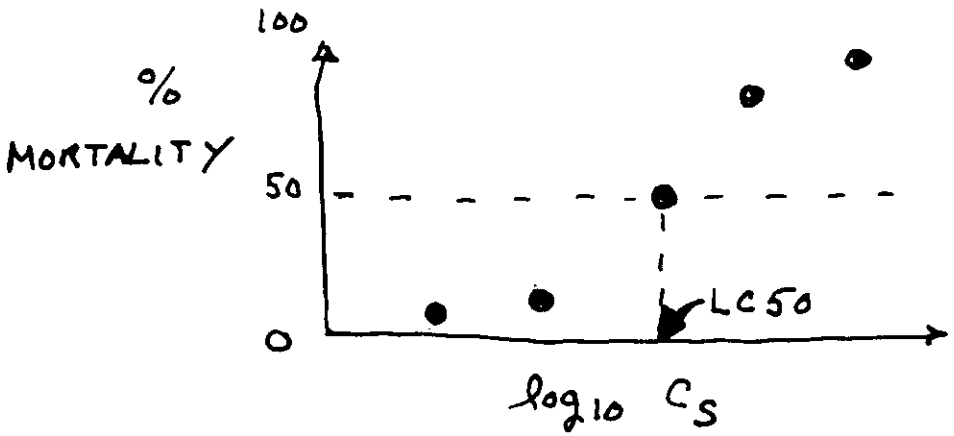
(~ < 0.1 % – 40 %)

SEDIMENT TOXICITY EXPERIMENT

PURPOSE : MEASURE EFFECT OF A CHEMICAL IN A SEDIMENT ON AN ORGANISM

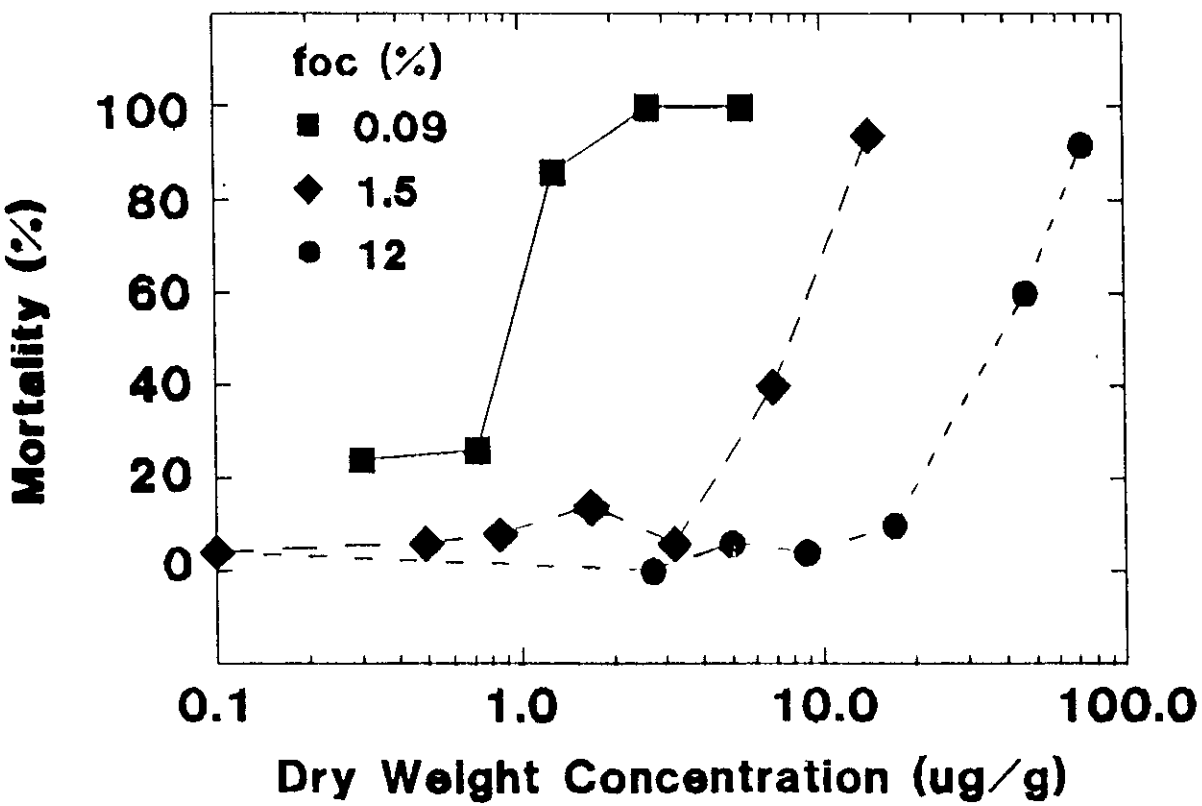


TYPICALLY : 5 CONCENTRATIONS, C_S



Acute Toxicity of Kepone

Dry Weight Normalization



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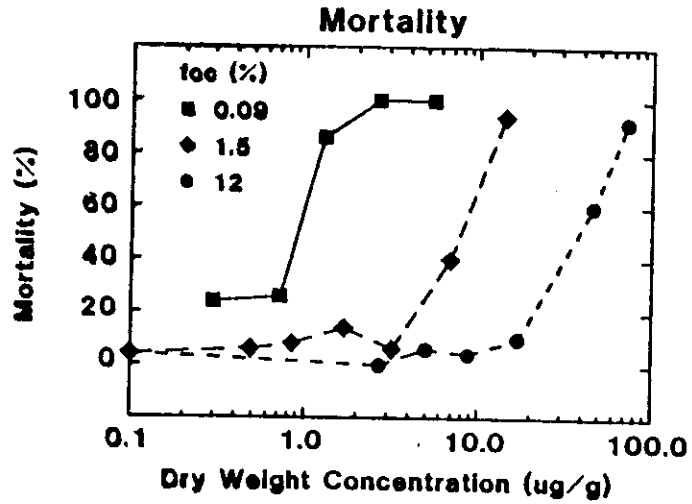
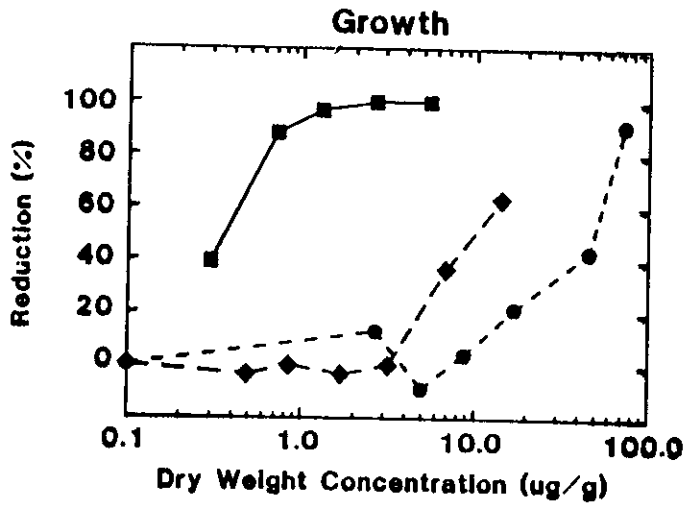
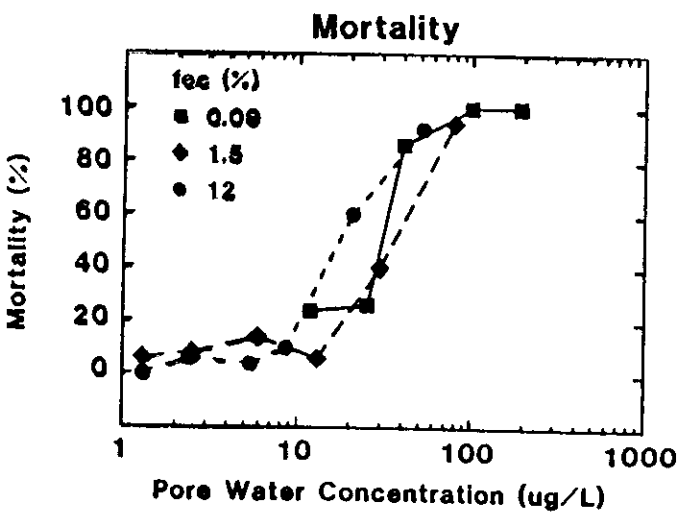
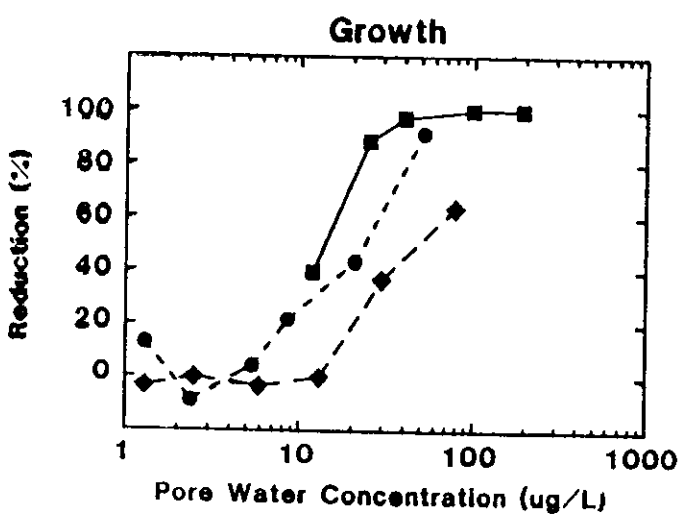
Acute and Chronic Toxicity of Kepone

Dry Weight and Pore Water Normalizations









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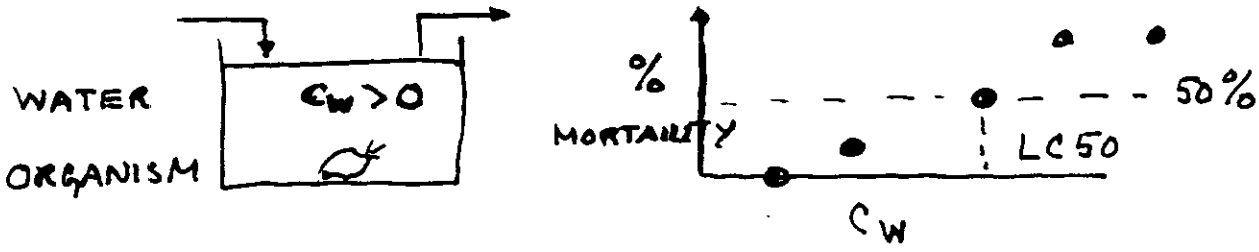
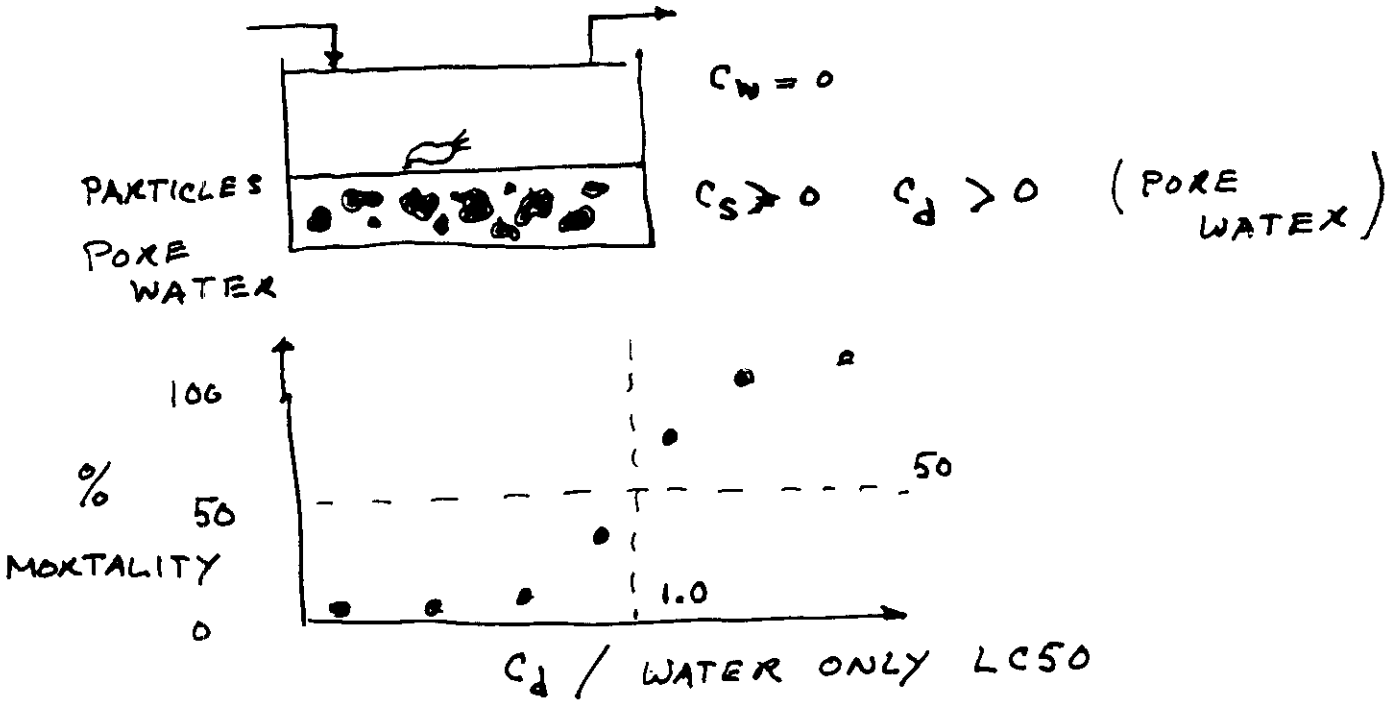
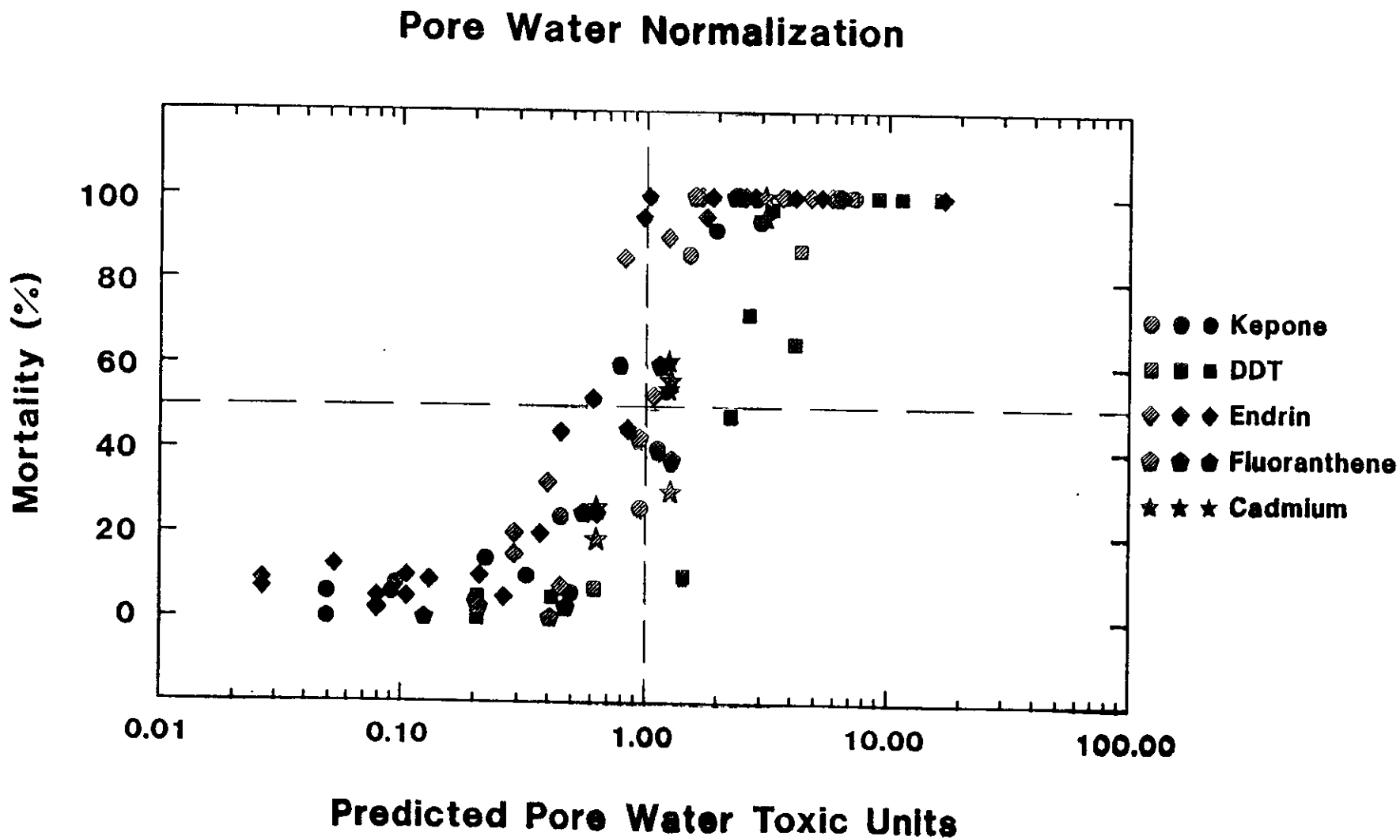
TOXICITY TESTS

WATER ONLY EXPOSURE



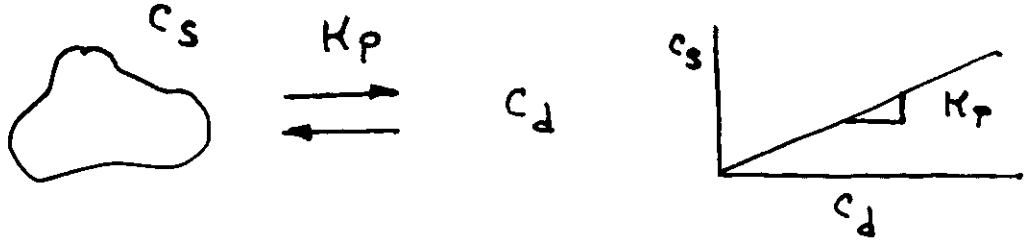
SEDIMENT EXPOSURE




Pore Water Normalization
Mortality (%)
100
80
60
40
20
0
0.01
0.10
1.00
10.00
100.00
Predicted Pore Water Toxic Units
Kepone
DDT
Endrin
Fluoranthene
Cadmium

b

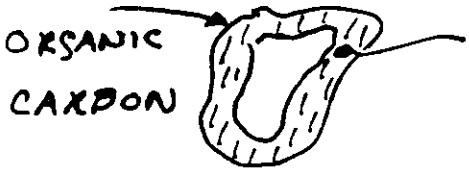
PARTITIONING BETWEEN PARTICLES AND PORE WATER



PARTITION COEFFICIENT

$$K_p = \frac{C_s \ (\mu g \text{ CHEMICAL}/g)}{C_d \ (\mu g \text{ CHEMICAL}/L)} \quad \left(\frac{L}{g}\right)$$

FOR NON-IONIC ORGANIC CHEMICALS



$$C_{s,OC} \underset{}{\overset{K_{OC}}{\rightleftharpoons}} C_d$$

WHERE : $C_{s,OC} = \dfrac{\mu g \text{ CHEMICAL}}{g \text{ ORGANIC CARBON}}$

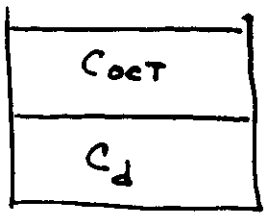
$$= C_s / f_{OC}$$

AND : $K_{OC} = K_p / f_{OC}$

IT HAS BEEN FOUND THAT :

K_{OC} IS INDEPENDENT OF SEDIMENT PROPERTIES ($f_{OC} > 0.2\%$)

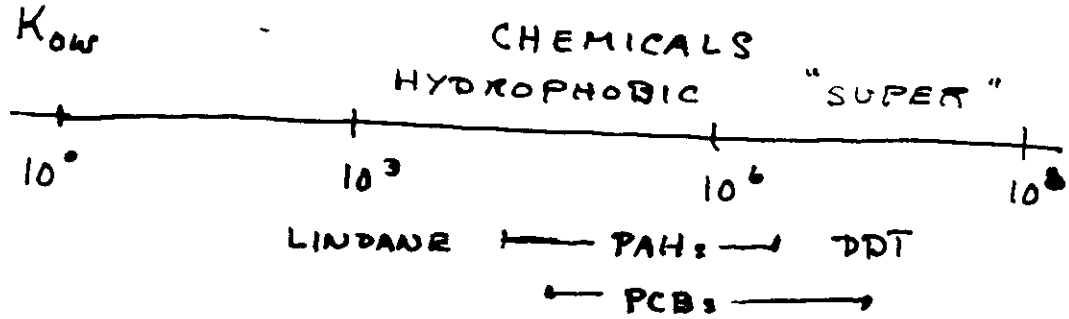
OCTANOL WATER PARTITION COEFFICIENT AND K_{OC}



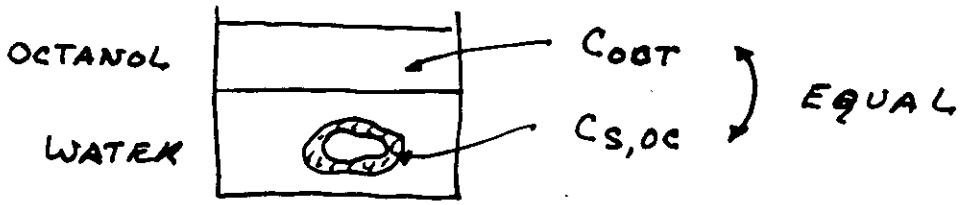
OCTANOL ($C_8 H_{17} OH$)

WATER

$$K_{OW} = \frac{C_{OCT}}{C_d} \quad \frac{(\text{mg CHEMICAL / L-OCTANOL})}{(\text{mg CHEMICAL / L-}H_2O)}$$



OBSERVATION : $K_{OC} \simeq K_{OW}$



I.E. CHEMICALS ARE ABOUT AS SOLUBLE IN ORGANIC CARBON AS THEY ARE IN OCTANOL

THEREFORE :

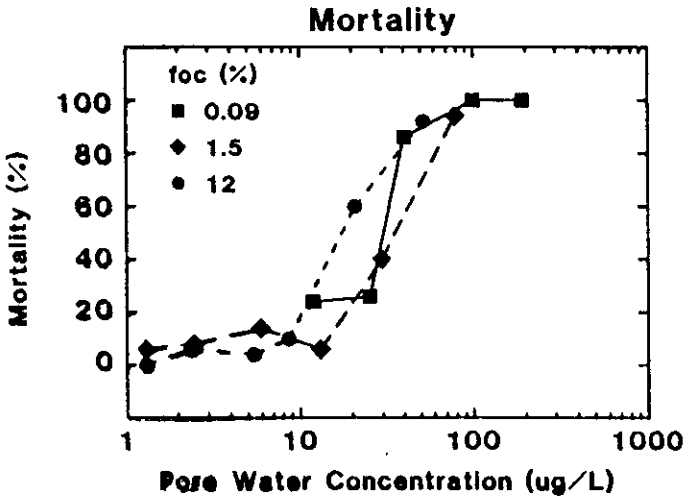
$$C_{S,OC} = \frac{C_S}{f_{OC}} = K_{OC}\, C_d \simeq K_{OW}\, C_d$$

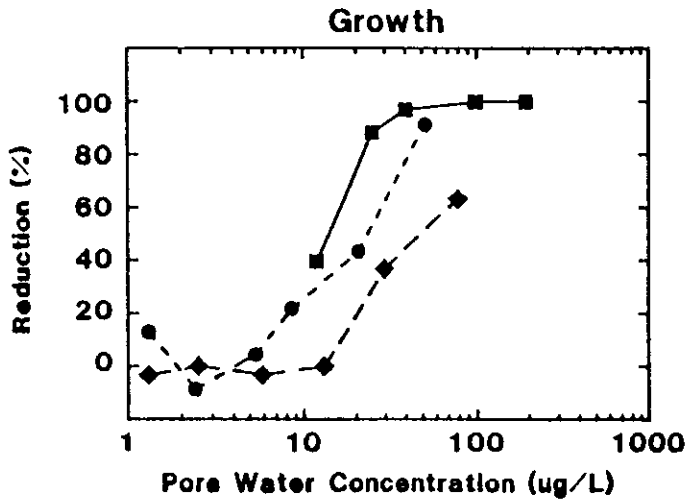
f_{OC} ← SEDIMENT PROPERTY

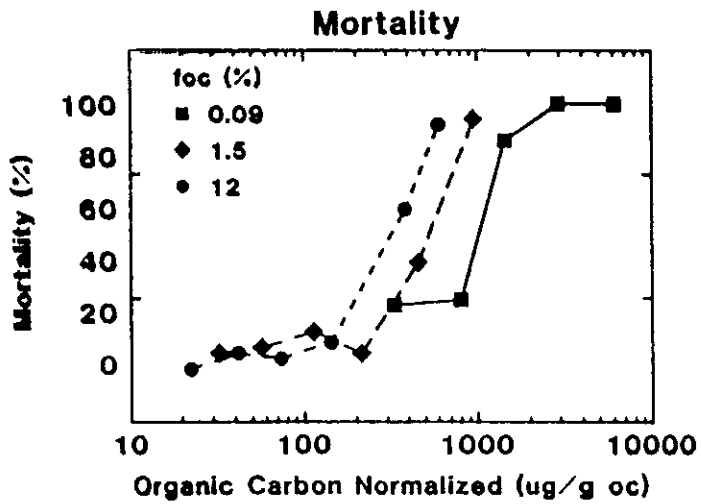
K_{OW} ← CHEMICAL PROPERTY

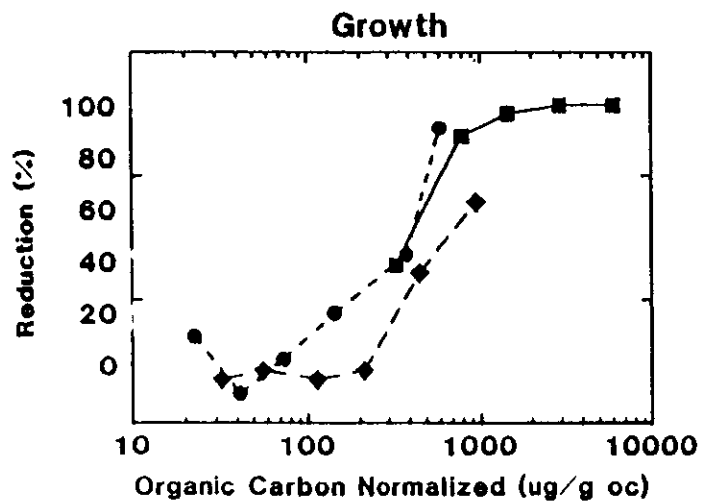
Acute and Chronic Toxicity of Kepone

Pore Water and Organic Carbon Normalizations









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Definition

Sediment Toxic Units: STU

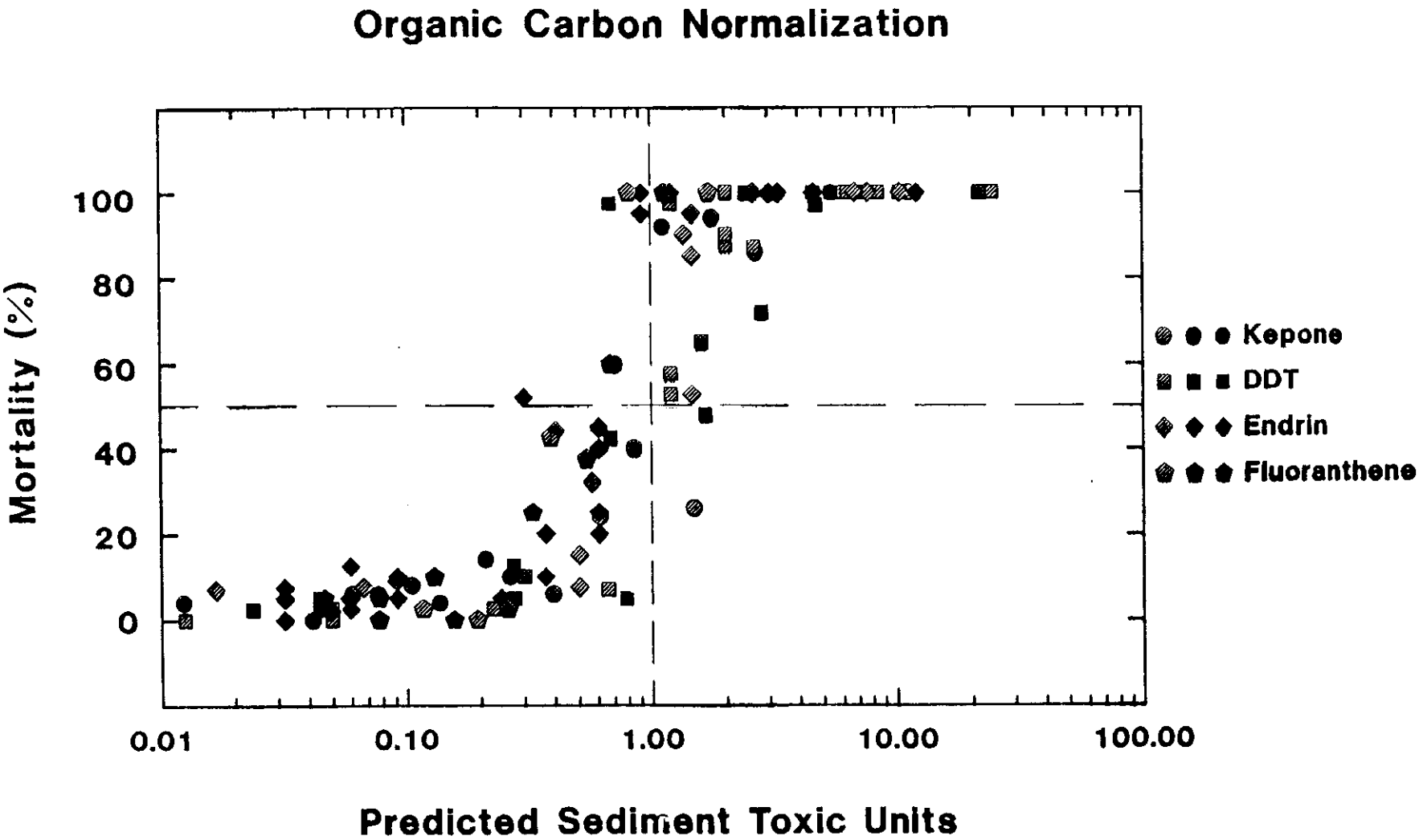
$$PTU = \frac{\text{Sediment Concentration}}{\text{Sediment LC50}}$$

Predicted Sediment Toxic Units: STU

Predict the sediment LC50

from the water only LC50 and K_{oc}.

$$STU = \frac{[\text{Sediment Concentration}]_{OC}}{K_{OC}[\text{Water Only LC50}]}$$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