Intercorrelations between Soil Constituent Concentrations and the Model-Inferred Methylmercury Absorption Efficiency by the Mudworm (*Lumbriculus variegatus*) Exposed to a Set of South Florida Peat Soils in a 28-Day Wet Soil Bioassay

R-19

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Abstract

Soil cores (0-4 cm) were collected and composited from 5 subunits of each of 50, 1,000-acre operational units in the potential footprint of the ~30,000-acre storage reservoir complex in the Everglades Agricultural Area in South Florida. The first-flush methylmercury (MeHg) production potential and bioavailability of these predominately peat soils were evaluated for 10 randomly selected samples using the mudworm (*Lumbriculus variegatus*) in a standard 28-day wet sediment bioaccumulation bioassay. In addition to total mercury (THg) and MeHg, post-bioassay wet soils were analyzed for moisture and ash content; total iron, manganese, and sulfur; and acid volatile sulfide (AVS). A one-compartment mathematical model of mudworm uptake and depuration was used to decorrelate the effect of soil moisture and organic carbon content from the effect on MeHg absorption efficiency in a mechanistically self-consistent way.

Abstract

(continued)

The MeHg absorption efficiency was calibrated to each of the observed worm MeHg concentrations using the analytic model (constant growth rate; constant soil MeHg concentration; depuration half-life = 16 days) and dynamic model (constant growth rate; sinusoidal soil MeHg concentration; depuration half-life = 16 days). The set of ($n = 8$) analytic or dynamic model-inferred worm MeHg absorption efficiencies was not statistically significantly ($p < 0.05$) positively correlated with any soil constituent or factor but was strongly inversely correlated only with THg conc. and %MeHg normalized to the %ash. When the 16-day half-life was replaced by a 6-day half-life, one of the calculated MeHg absorption efficiencies was greater than 1, suggesting the possibility of MeHg production in the worm gut.

Background

- See Poster R-18

Methods

- See Poster R-18

Model Development

- See Poster R-17

$$dCO(t)/dt = CS(t) \times IR(t) \times AE - KD \times CO(t) - KG \times CO(t)$$

Where:

CO	=	conc. toxicant in test organism (mg/Kg wet wt.)
CO(0)	=	conc. toxicant in test organism at time t = 0
CS	=	conc. toxicant in sediment, soil, or ration (mg/Kg wet wt.)
IR	=	organism ingestion rate per unit wet body wt.
AE	=	toxicant absorption efficiency by gut (unitless)
KD	=	depuration rate coefficient (day-1)
BW	=	test organism wet body weight (Kg)
KG	=	1/doubling time (day-1)

Analytic Time-Dependent Solution

$$CO(t) = [CS \times IR \times AE/(KD + KG)] \times EXP(-(KD + KG) \times t) + CO(0) \times EXP(-(KD + KG) \times t)$$

IRTS = IRRS x [RSfoc/TSfoc] x [(1-RSm)/(1-TSm)] x [RSbev/TSbev] x [1-ROm]/[1-TOm]

Where:

IRTS, IRRS = ingestion rate of test ration, sediment, or soil and reference sediment, respectively.

RSfoc, TSfoc = fraction organic carbon of reference sediment and test ration, sediment, or soil, respectively

RSm, TSm = fraction moisture reference sediment and test ratio, sediment, or soil, respectively.

RSbev, TSbev = bioenergetic value of reference sediment and test ration, sediment, or soil to test organism, respectively.

ROm, TOm = fraction moisture of reference and test organisms, respectively

Doubling Time = TOfoc/(IRTS x TSfoc x TSbev x TOce)

Where:

TOfoc = test ration, sediment, or soil fraction organic carbon.

IRTS = test ration, sediment, or soil ingestion rate.

TSbev = bioenergetic value of test ration, sediment, or soil to test organism.

TOce = conversion efficiency of bioenergetically bioavailable organic carbon converted to test organism biomass.

Parameterization

- KD = 0.693/16 days
- KG = 1/8 days
- RSfoc, TSfoc = 0.035; (1-%ash*/100%) x 0.48
- RSm, TSm = 0.85; (%moist*/100%)
- RSbev, TSbev = 0.175; 0.15
- ROm, TOm = 0.88; 0.88*
- TOfoc = 0.32
- TOce = 0.55

* measured value

Procedure

- Analytic Solution: constant soil MeHg conc. & mudworm growth rate; $t_{1/2}$ = 16 d or 6 d.
- Dynamic Solution: per observed sinusoidal wet soil MeHg conc. (Fig. 1).
- Calibration: absorption efficiency (AE) of steady-state or dynamic (sinusoidal) mudworm MeHg bioaccumulation model adjusted until equal observed and predicted mudworm MeHg concs.
- Statistical Analysis: Linear nonparametric univariate (Spearman) analysis of set of calibrated AEs vs. Phase 2 soil parameters and ratio Phases 2/1 for THg, MeHg, and %MeHg.

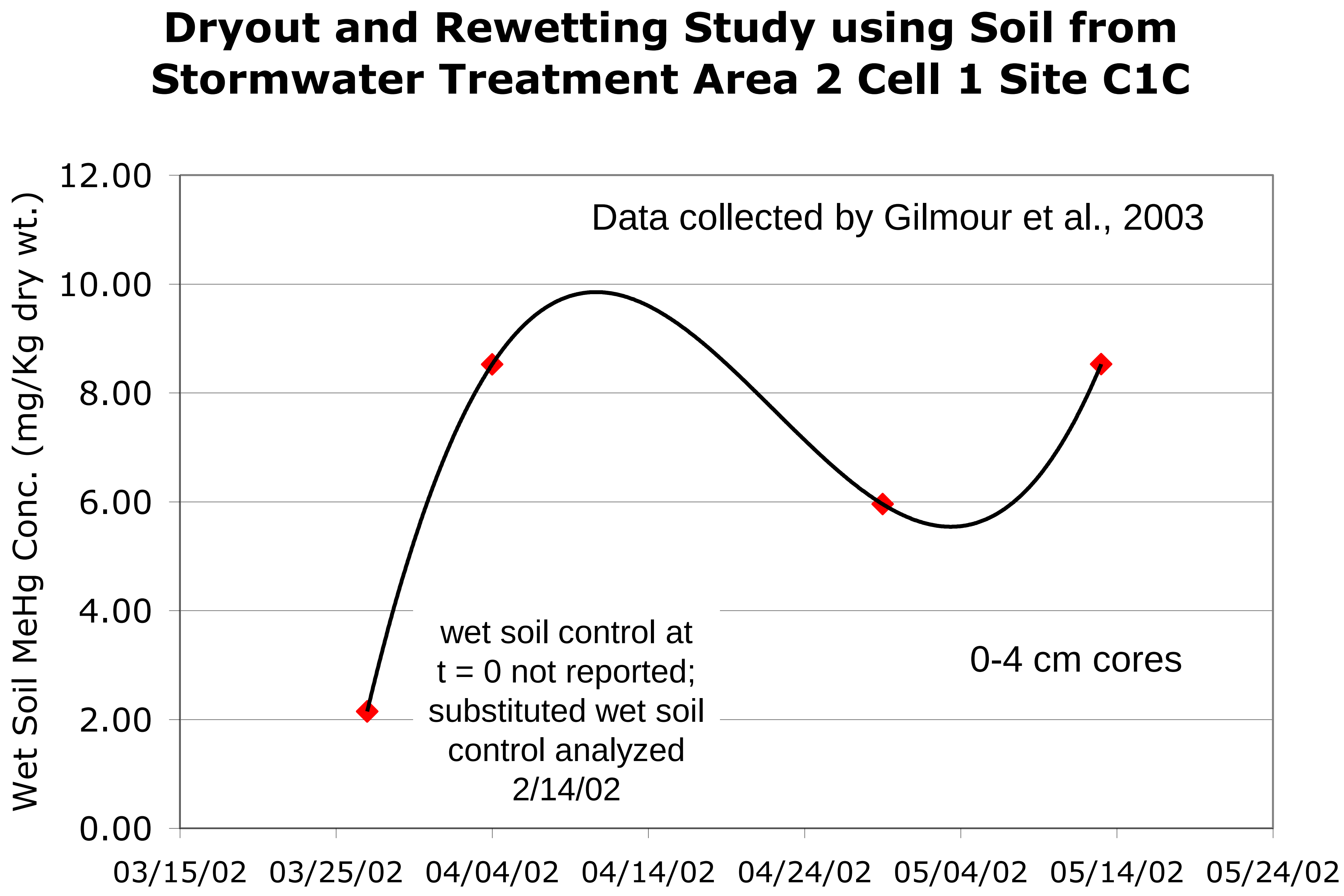

Figure 1. Wet soil methylmercury concentration over time following rewetting of soil collected from Stormwater Treatment Area 2 Site C1C after drying for 45 days.

Results of Model Calibration

$t_{1/2}$ = 16 days	Calibrated AE Analytic Solution	Calibrated AE Dynamic (See Fig 2)	$t_{1/2}$ = 6 days	Calibrated AE Analytic Solution	Calibrated AE Dynamic (See Fig 3)
SEAAOU5	**0.9175**	**0.481**	SEAAOU5	**1.42**	**0.651**
SEAAOU7	**0.55**	**0.292**	SEAAOU7	**0.86**	**0.396**
SEAAOU17			SEAAOU17		
SEAAOU20	**0.235**	**0.19**	SEAAOU20	**0.56**	**0.267**
SEAAOU23	**0.31**	**0.21**	SEAAOU23	**0.615**	**0.29**
SEAAOU34	**0.26**	**0.168**	SEAAOU34	**0.49**	**0.232**
SEAAOU39	**0.32**	**0.26**	SEAAOU39	**0.76**	**0.364**
SEAAOU41	**0.16**	**0.1015**	SEAAOU41	**0.3**	**0.14**
SEAAOU46			SEAAOU46		
SEAAOU48	**0.128**	**0.1035**	SEAAOU48	**0.3**	**0.145**

$t_{1/2}$ = 16 d

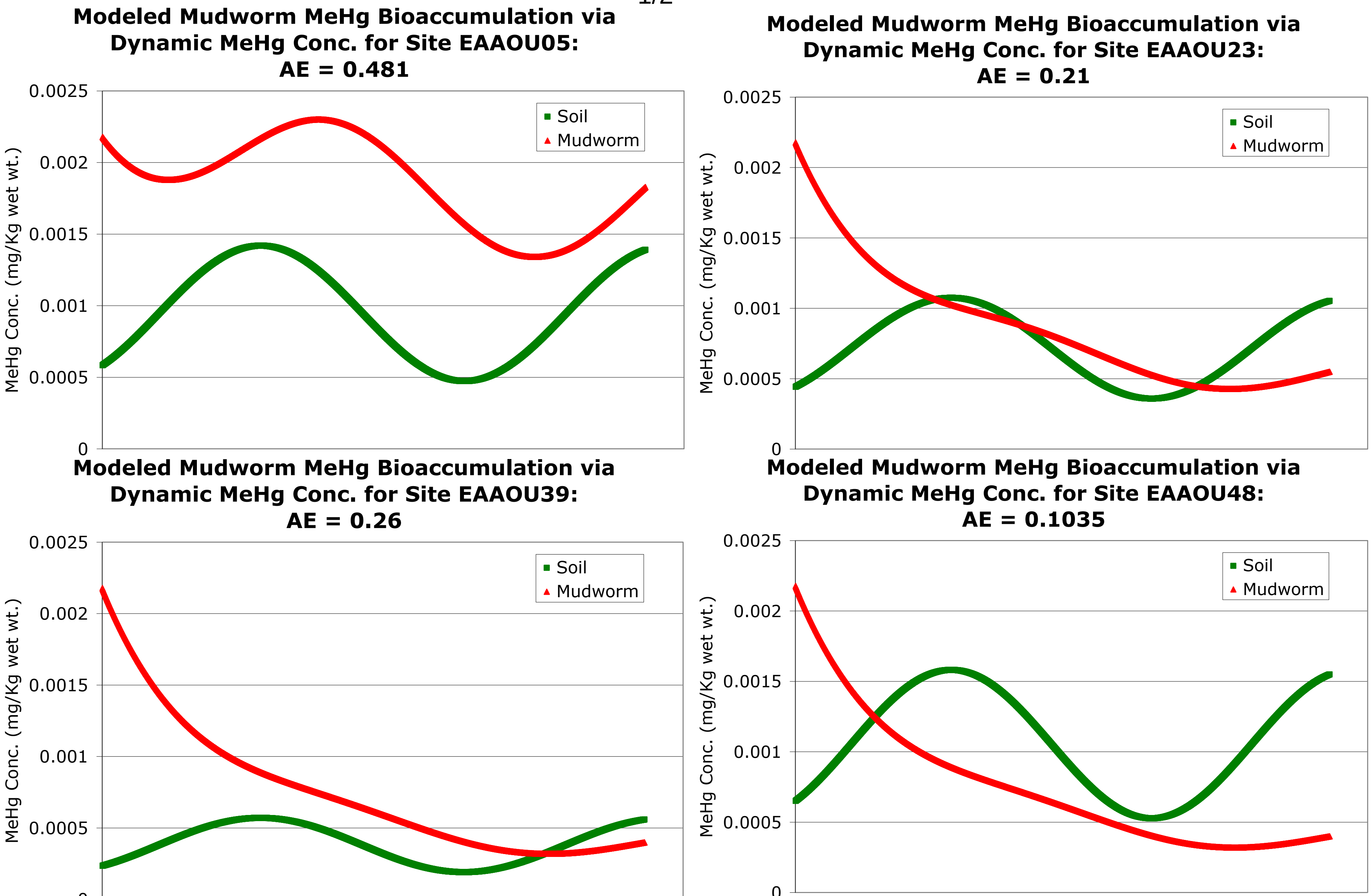

Figure 2. Mudworm MeHg bioaccumulation over time per dynamic solution with assumed sinusoidal wet soil MeHg conc.; depuration half-life = 16 d

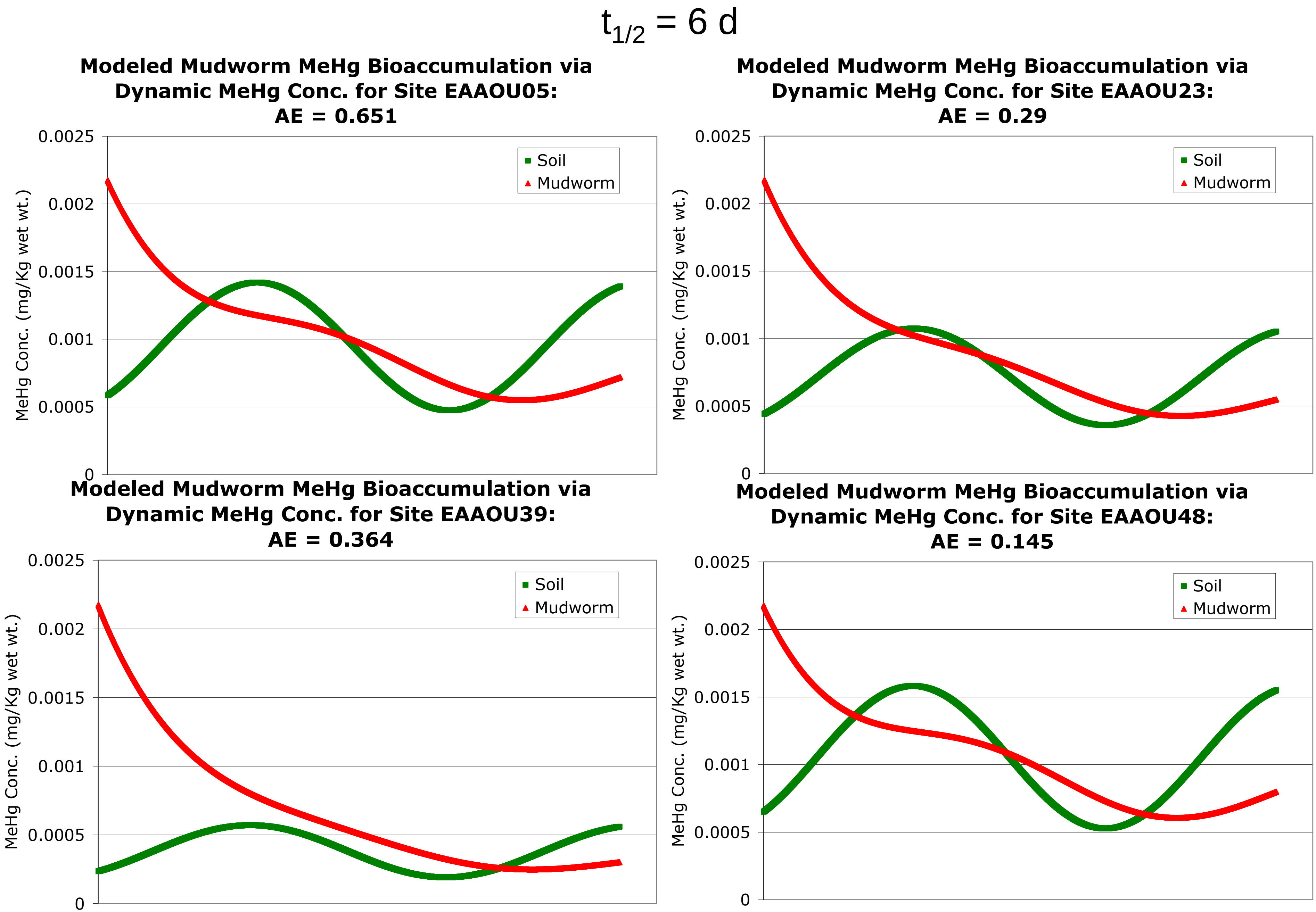

Figure 3. Mudworm MeHg bioaccumulation over time per dynamic solution with assumed sinusoidal wet soil MeHg conc.; depuration half-life = 6 d

Results of Inter-correlation Analysis

Nonparametric Spearman Correlation Coefficient

	AE Analytic Solution
Soil THg	**-0.802**
Soil MeHg	-0.524
Soil %MeHg	0.048
Worm THg	0.429
Worm MeHg	0.561
Worm %MeHg	**0.738**
THg SBAF	0.429
MeHg SBAF	**0.929**
MeHg SBAFOM	0.619
Ratio %MeHg	0.500
ASH	0.357
MOIST	-0.405
TFE	-0.357
TMN	-0.217
TS	-0.167
AVS	-0.238
MeHg/fom	0.238
%MeHg/%ash	**-0.786**
MeHg/fH20	0.000
THg P2/P1	-0.238
MeHg P2/P1	0.619
%MeHg P2/P1	0.595
AE analytic soln.	1

$t_{1/2}$ = 16 days

Key Findings and Conclusions

- Nonparametric covariance analysis of analytic solution results indicates MeHg AE from EAA peat soils strongly inversely correlated with soil THg & organic matter (%MeHg/%ash) but not moist., TS, AVS, TFe, TMn.
- Soil MeHg strongly positively correlated with THg; %MeHg weakly inversely correlated with THg, strongly positively with ash and strongly inversely with moisture, TS, TMn, but not AVS.
- … so cannot tell if strong inverse relationship is real (e.g., reduction in ingestion rate due to $Hg(II)^{2+}$ toxicity) or an artifact.
- However, delay in burrowing suggests former.

Recommendations

- Availability of measured mudworm ingestion & growth rates and oc assimilation efficiency will reduce analytic and dynamic model propagated error with corresponding increase in resolution of & confidence in statistical inferences.
- Standard mudworm bioassay method should be modified to measure these parameters when evaluating factors influencing bioavailability.

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References

Gilmour, C., D.P. Krabbenhoft, W. Orem, and G. Aiken. 2003. Influence of Drying and Rewetting on Hg and S Cycling in Everglades and STA Soils. Academy of Natural Sciences, St. Leonard, MD and the U.S. Geological Survey, Middleton, WI, Reston, VA, and Boulder, CO. Report to the South Florida Water Management District, West Palm Beach, FL.

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