Middleport Biomonitoring and Bioavailability Studies

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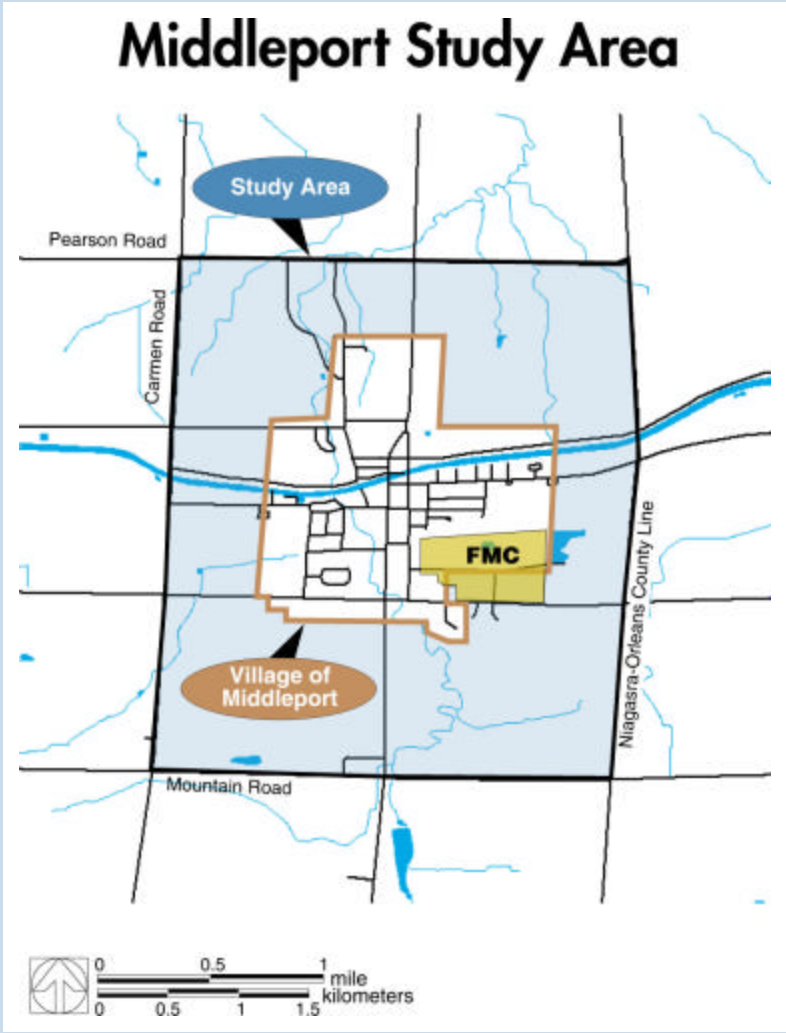
Middleport Environmental Exposure Study - 2003

- Conducted by Exponent independent of FMC
- Review of study design and results overseen by an independent panel of experts*
- Participation was voluntary
- Results have been published in *Env. Health Perspectives*, a peer-reviewed journal



*Members of the scientific advisory panel:
D. Barr, R. Bornschein, F. Frost Jr., D. Gute, P. Kostecki, H. Pastides, and P. Succop

Middleport Environmental Exposure Study Design

- Participants – 439 of 1,930 residents in study area, including 77 of 164 children < 7 years old.
- Collected first morning urine sample on 2 days, analyzed for total and speciated As and for creatinine, plus toenail samples (84).
- Collected soil from yards (84), gardens (23), and play areas (28), plus indoor dust (111) and vegetables (42 gardens).
- Administered questionnaire on demographic, socioeconomic, and behavioral information and housing characteristics.

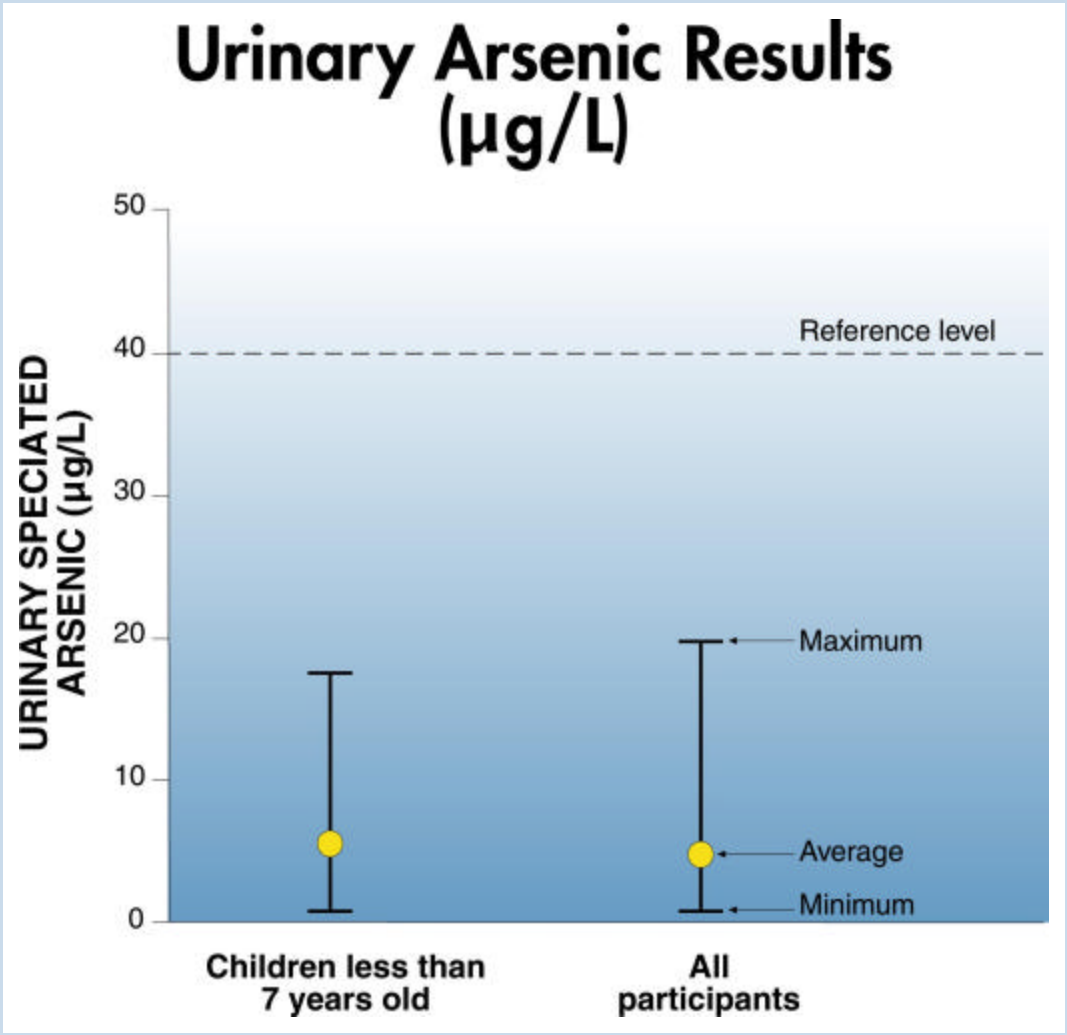
Middleport Study Results

Participants (number)	Mean yard soil As (ppm)	Mean house dust As (ppm)	Mean urinary speciated As (ug/L)
All (439)	28	20.3	4.7
Children <7 years (77)	22.5	21.8	5.3

Middleport Environmental Exposure Study Analyses

- All *speciated arsenic levels in urine* were below 20 µg/L, were generally lower than other populations tested, and did not correlate with arsenic in soil and dust.
- *Total arsenic levels in urine* were above 50 µg/L in 26 participants, likely due to seafood consumption.
- *Arsenic levels in vegetables* were variable and highest in late season leafy greens. Produce consumption did not cause urine arsenic levels to increase.

Middleport Study Results

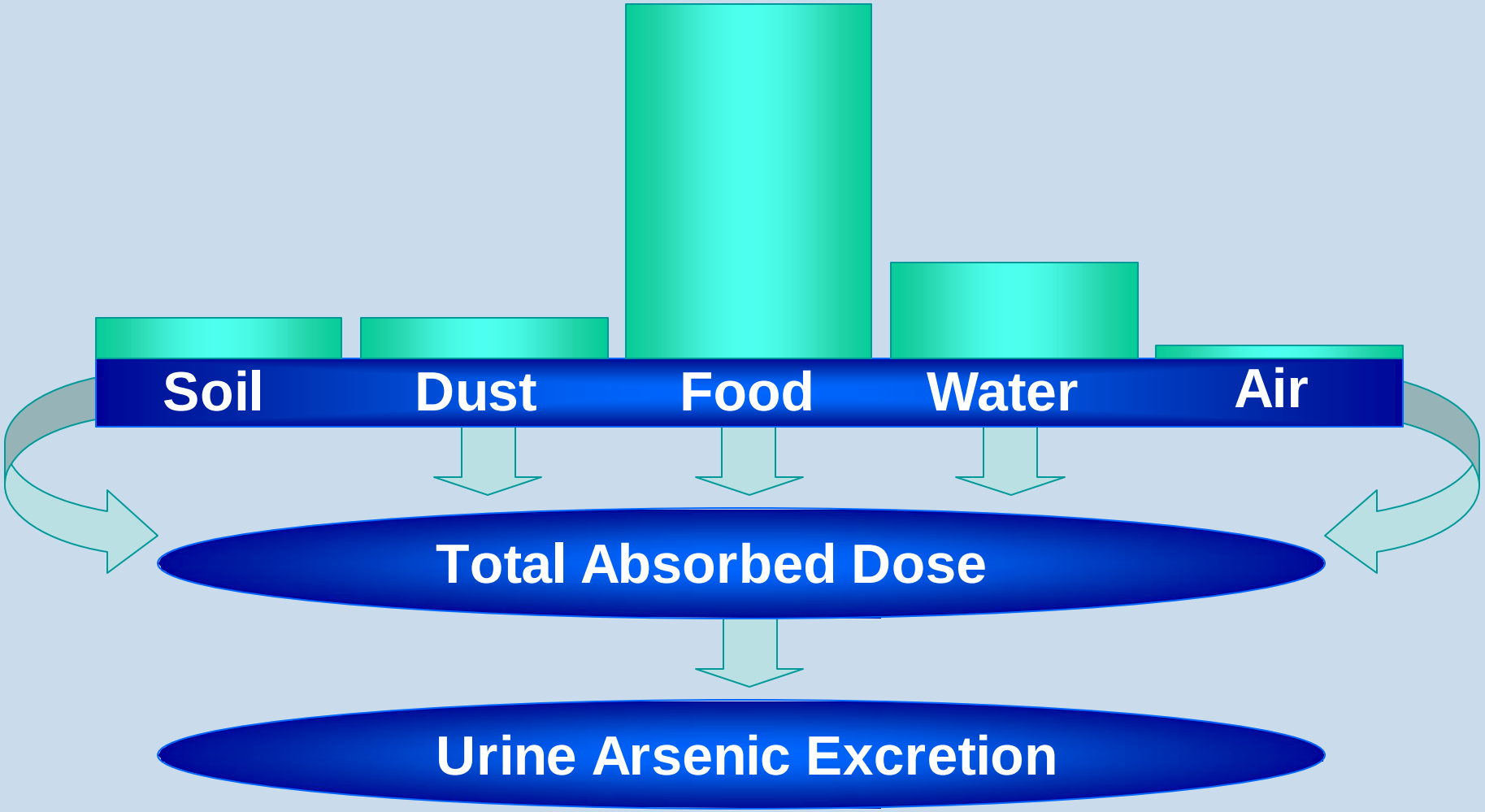


*Urine arsenic results may be compared to reference levels to identify individuals who may have elevated exposure. Reference levels for speciated urine arsenic have varied. 40 µg/l of speciated arsenic was used as the reference level for this study. 50 µg/l was used as a reference level for total urine arsenic.

Why are soil arsenic exposures not identifiable in individuals?

- Little soil is ingested
- Less arsenic is absorbed into the body from soil than from food and water (reduced bioavailability)
- Soil arsenic exposures are much less than normal, everyday exposures to arsenic naturally present in food and drinking water
- Because there is lots of day-to-day variability in arsenic intake from food, little doses from soil can only be assessed in a large study such as was conducted in Middleport

Contributions to Background Arsenic Exposures



How Much Arsenic Are We Exposed to Naturally?

Source of Exposure	Average Dose for Child[a] (µg/day)	Average Dose for Adult[a] (µg/day)
Food	**1.3 – 3.7**	**3.2 – 7.4**
Water, 10 µg/L (MCL)	**6.0**	**14**
Water, 1 µg/L	**0.6**	**1.4**
Soil, 20 ppm or 30 ppm	**0.5 or 0.75**	**0.25 or 0.38**
Soil, 40 ppm or 50 ppm	**1.0 or 1.25**	**0.5 or 0.63**
Air, 0.025 µg/m^3	**0.17**	**0.33**

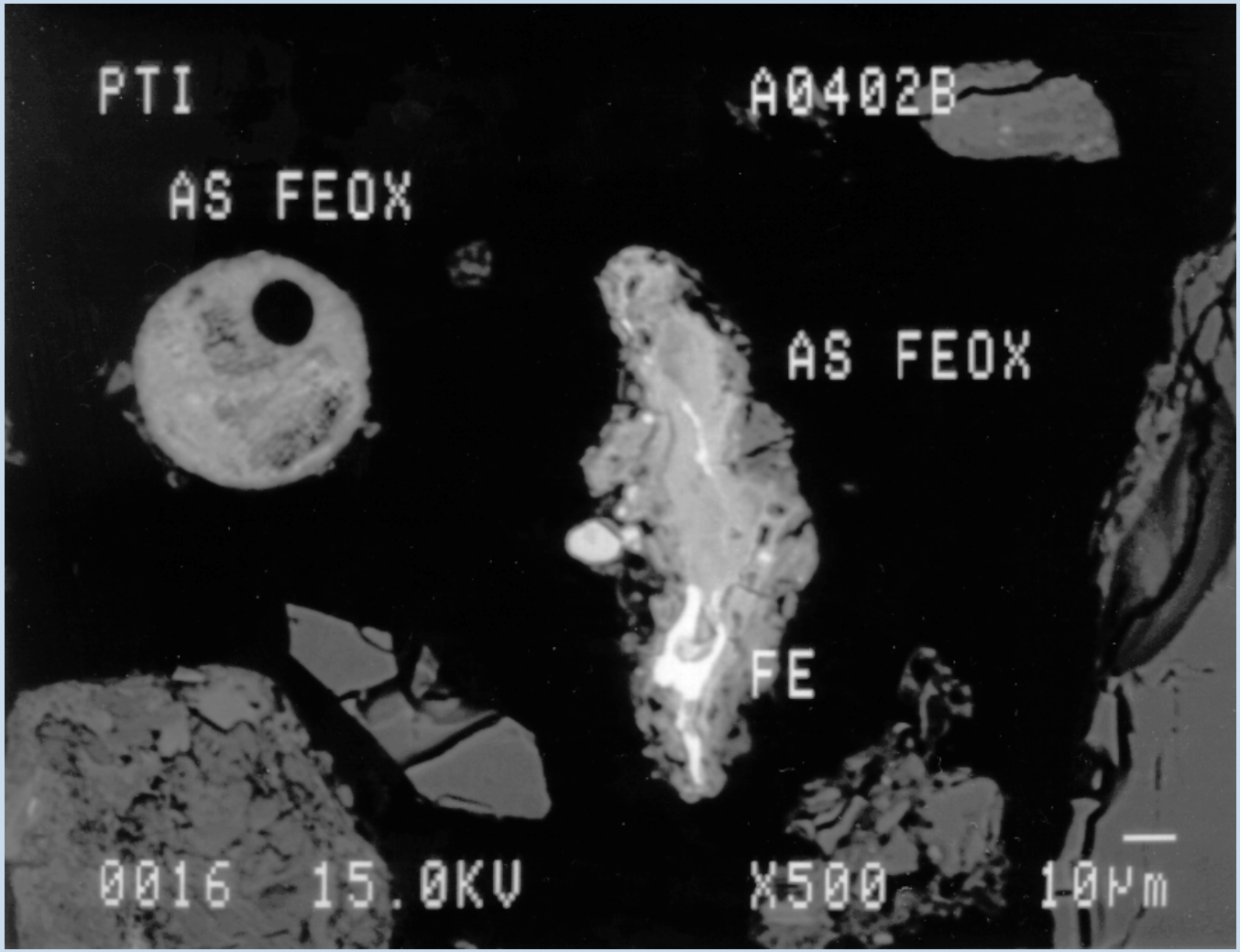
[a]Assumes child drinks 0.6 liters of water, ingests 0.1 g soil, and inhales 6.8 m^3 air, and that adult drinks 1.4 liters of water, ingests 0.05 g soil, and inhales 13.3 m^3 air, and that relative bioavailability of arsenic in soil is 0.25

What bioavailability studies have been done with Middleport soils?

- 1995 study showed arsenic bioavailability was only 20 percent compared to arsenic dissolved in water.
- Recent studies directed by Yvette Lowney and Mike Ruby of Exponent (part of SERDP grant).
- Electron microprobe studies have found less soluble mineral forms of arsenic in Middleport soil (Univ. of CO).
- An oral bioavailability study in monkeys has shown reduced arsenic absorption from soil (19-28% relative bioavailability)(Univ. of FL).
- A monkey study of dermal absorption has shown that soil arsenic absorption across skin is negligible (Univ. of CA).

Soil Arsenic Mineralogy Supports Bioavailability Study Results

Most arsenic is associated with iron oxides or arsenic-iron oxides.



Photomicrograph of Arsenic-Iron Oxide Grain

Relative Oral Bioavailability Studies of Arsenic in Cynomolgus Monkeys

- Conducted by Dr. Stephen Roberts at the University of Florida.
- Results for 14 soils from 12 sites.
- Positive and negative reference materials also tested.
- Results published in 2007 in *Toxicological Sciences* (peer reviewed journal of the Society of Toxicology).

Soil Arsenic Relative Bioavailability

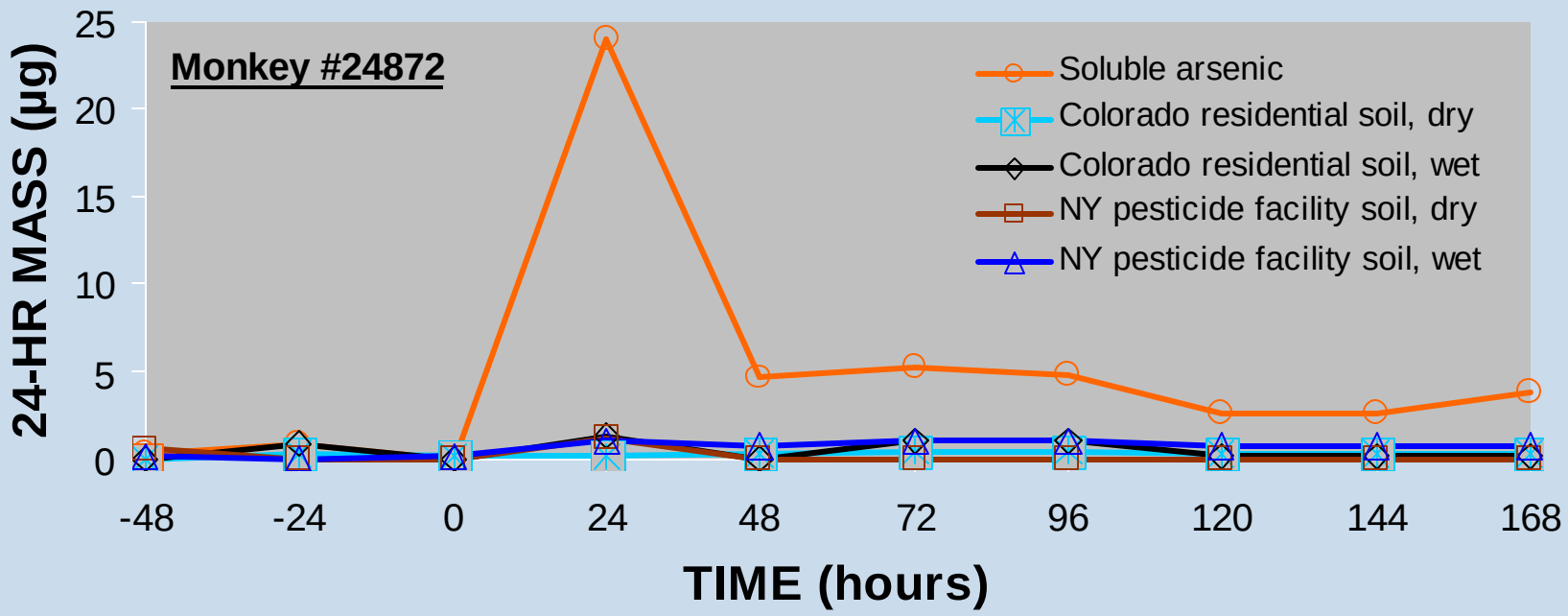
Soil Sample	Relative Bioavailability[a]
WAOS	**0.24** ± 0.09
NYOS	**0.15** ± 0.08
NYF-5B	**0.19** ± 0.05
NYF-8B	**0.28** ± 0.10
NYF-13B	**0.20** ± 0.10
AsPyrite spike	**0.002** ± 0.003
Arsenate spike	**0.94** ± 0.05

[a] Relative Bioavailability = % Dose in urine (soil) / % Dose in urine (arsenate)
Results expressed as mean ± SD (N=5)

Study of Dermal Absorption of Arsenic From Middleport Soils

- Study conducted by Dr. Wester of UCSF who directed the 1993 study cited in EPA dermal exposure guidance.
- Used same animal model, but adapted to test weathered soils.
- Study results now “in press” in *Toxicological Sciences.*

Dermal Arsenic Absorption Results



While EPA assumes that 3% of arsenic on skin is absorbed, the UCSF study found that absorption is negligible with an average of less than 0.5% absorbed.

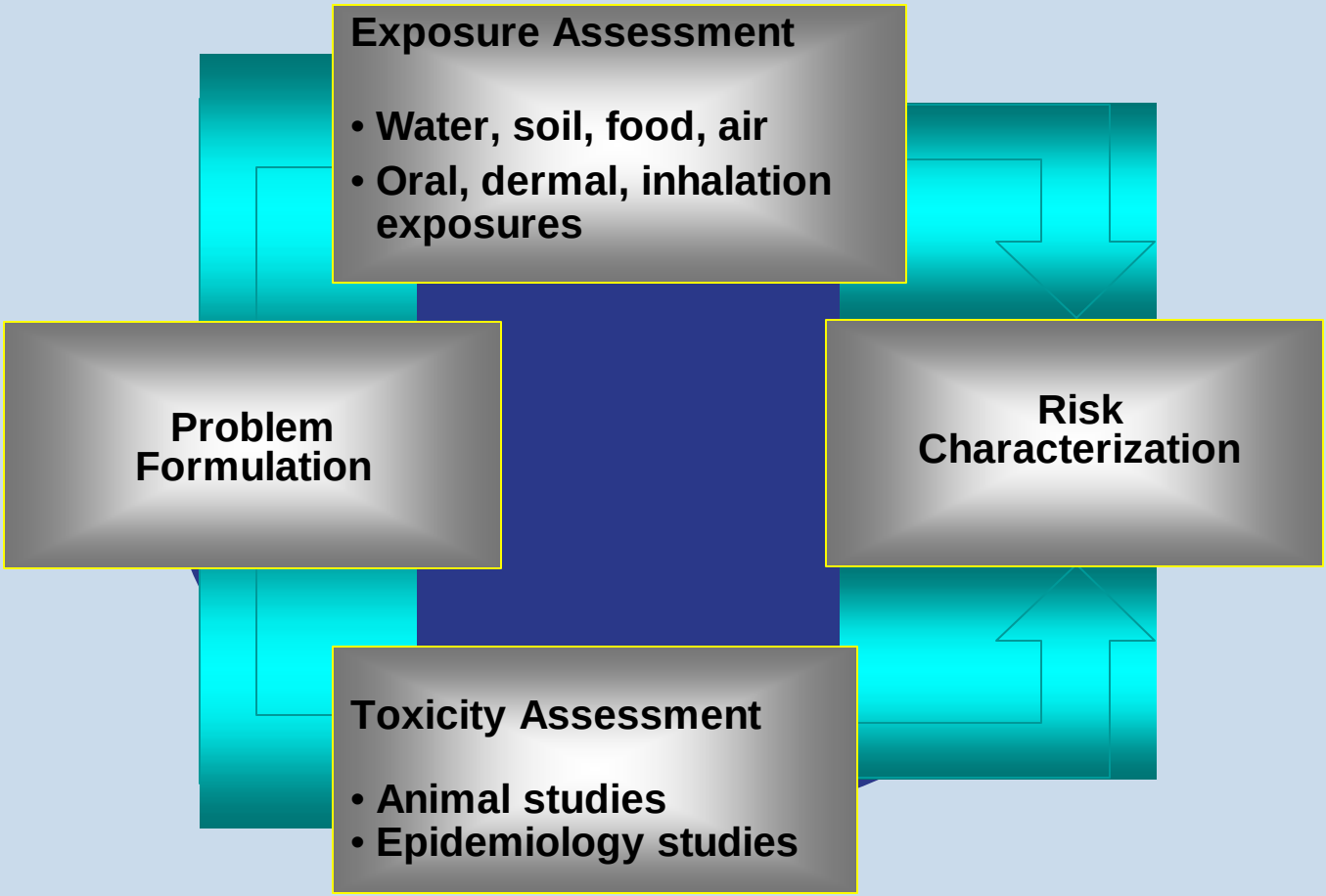
General Conclusions

- Low level As presence in soils (i.e., <50ppm) is widespread in the U.S.
- In most cases, the amount of As that could be absorbed from soils is small compared to natural sources (i.e., diet)
- There is no measurable difference in exposure and health risk from soil containing 20 or 50 ppm of arsenic

Conclusions for Middleport

- Biomonitoring study showed that Middleport residents do not have elevated arsenic exposures.
- Recent studies have shown that children ingest less soil than EPA assumes.
- Bioavailability studies show that oral absorption is reduced and dermal absorption is negligible.
- Risk assessment should incorporate these findings.

How is this information relevant to risk assessment?



Putting Soil Exposures in Context

- Risk estimates for exposure to arsenic in soil can be better understood if the doses from soil are added to the doses from natural arsenic in food, water and air
- Daily doses per kilogram of body weight are higher for children than for adults because they eat more than adults relative to body weight
- In risk assessment adult and child doses are combined (assuming a total of 30 years of exposure, 6 years as a young child and 24 years as an adult)
- For cancer risk, the doses are then averaged over a 70 year lifetime (this is the “risk dose” in the table)

How Much Influence Does Soil Have on Daily Arsenic Exposure?

Ranges of Total Daily Arsenic Dose from all Background Sources[a]

	Child (µg/day)	Adult (µg/day)	Risk Dose µg/kg BW
Diet + water + air	**2.1**	**4.9**	**0.036**
Diet, water, air + 20 ppm soil	**2.6**	**5.2**	**0.040**
Diet, water, air + 30 ppm soil	**2.8**	**5.3**	**0.042**
Diet, water, air + 40 ppm soil	**3.1**	**5.4**	**0.044**
Diet, water, air + 50 ppm soil	**3.3**	**5.6**	**0.046**

[a]Assumes child drinks 0.6 liters of water, ingests 0.1 g soil, and inhales 6.8 m^3 air, and that adult drinks 1.4 liters of water, ingests 0.05 g soil, and inhales 13.3 m^3 air, and that relative bioavailability of arsenic in soil is 0.25. For cancer risk dose, assumes child exposure is 6 years at 15 kg body weight, adult exposure is 24 years at 70 kg body weight, soil dose averaged over 70 year lifetime.