Advanced Decision Unit – Multi Increment Sampling (DU-MIS)- Problems, Pitfalls and Pearls

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Plan of Attack

Case Study Site

Decision Unit (DU) Design

- Number of Increments in DU
- Sample Mass Critical
- Mixing Populations
- “Compound Specific Heterogeneity”

What is Reproducible Environmental Data?

- Percent Relative Standard Deviation (%RSD)
- What do you do when your data doesn’t meet %RSD

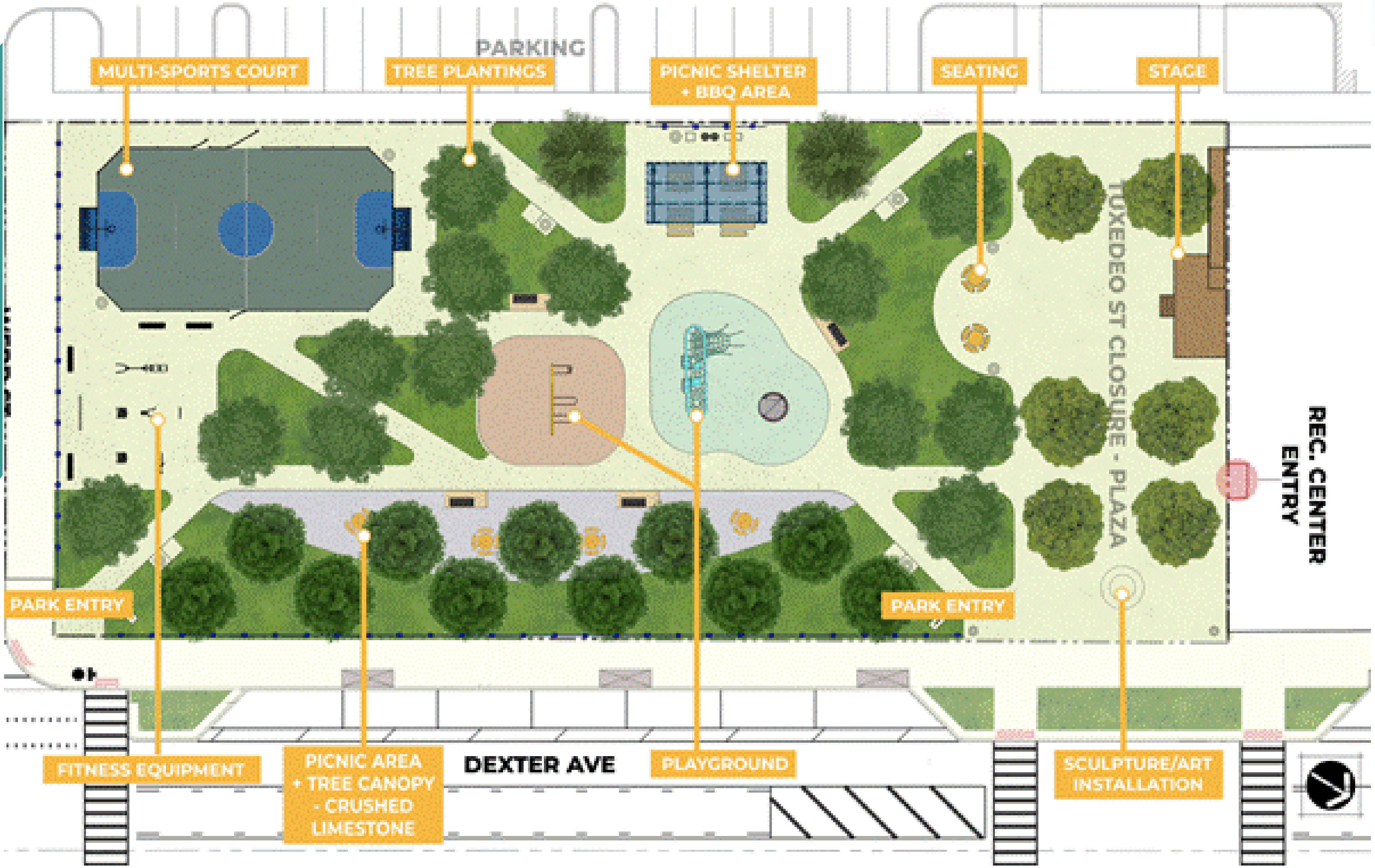
Questions ???

Rendering Courtesy of: The City of Detroit

Helen Moore Community Center, Detroit, MI

Rendering Courtesy of: The City of Detroit

Ed Davis Park, Detroit, MI



Decision Unit (DU) Design

Volume (Area?) about which a decision is to be made

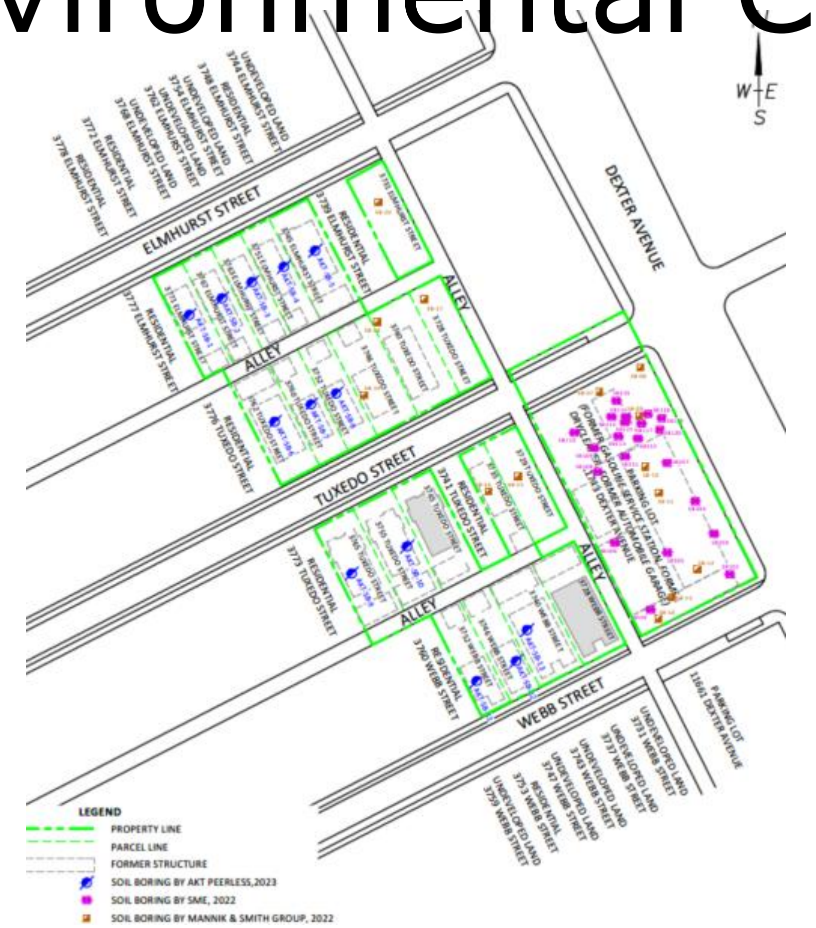
Reason for Sampling: Exposure Evaluation or Maximize Remediation Efficiency

Representative, Reproducible, Defensible (RRD)

Chuck Ramsey's Definition A **representative** sample is a sample or collection of samples that answers a question about a population with a specified confidence.

Simply it's the total volume of soil in the DU, but…..

Case Study: Historical Environmental Concerns



❖11743 Dexter Avenue:

- Gasoline Service Station
- Dry Cleaner
- Automobile Garage
- Potential for urban fill

❖Remaining Parcels:

- Potential for urban fill

Site Plan Courtesy of: The City of Detroit

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Case Study: Development Plan

❖11743 Dexter Avenue
- Park and Plaza

❖Remaining Parcels
- Parking Lot, Park, and Green Space Areas

Number of Increments in a DU

*"**A minimum of 30-50 increments per DU** is recommended to obtain a representative and reproducible estimate of the mean concentration in a DU that has **moderate heterogeneity**."**

Based on the heterogeneity of the DU

Based on the heterogeneity of the DU

Not related to area/volume of DU

>100 increments is unnecessary

Shallow surficial DUs - # of increments should not impact on cost

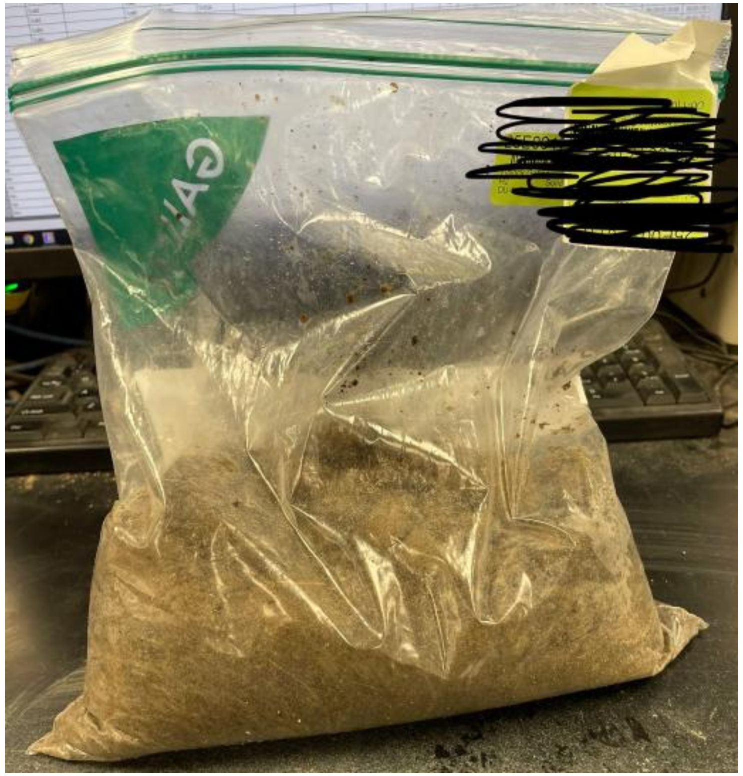
Deep DUs – More Expensive – Do we really need?

* - EGLE RRD Incremental Sampling Technical Resource signed 2018

Sample Mass

"Sweet Spot" for Sample Mass is 1-2kg

DU-MIS Sample Mass is dictated by the number of increments, the diameter of the sample tool, and the thickness of the DU



Choosing the Correct Sampler

Sample Mass

Increment Diameter

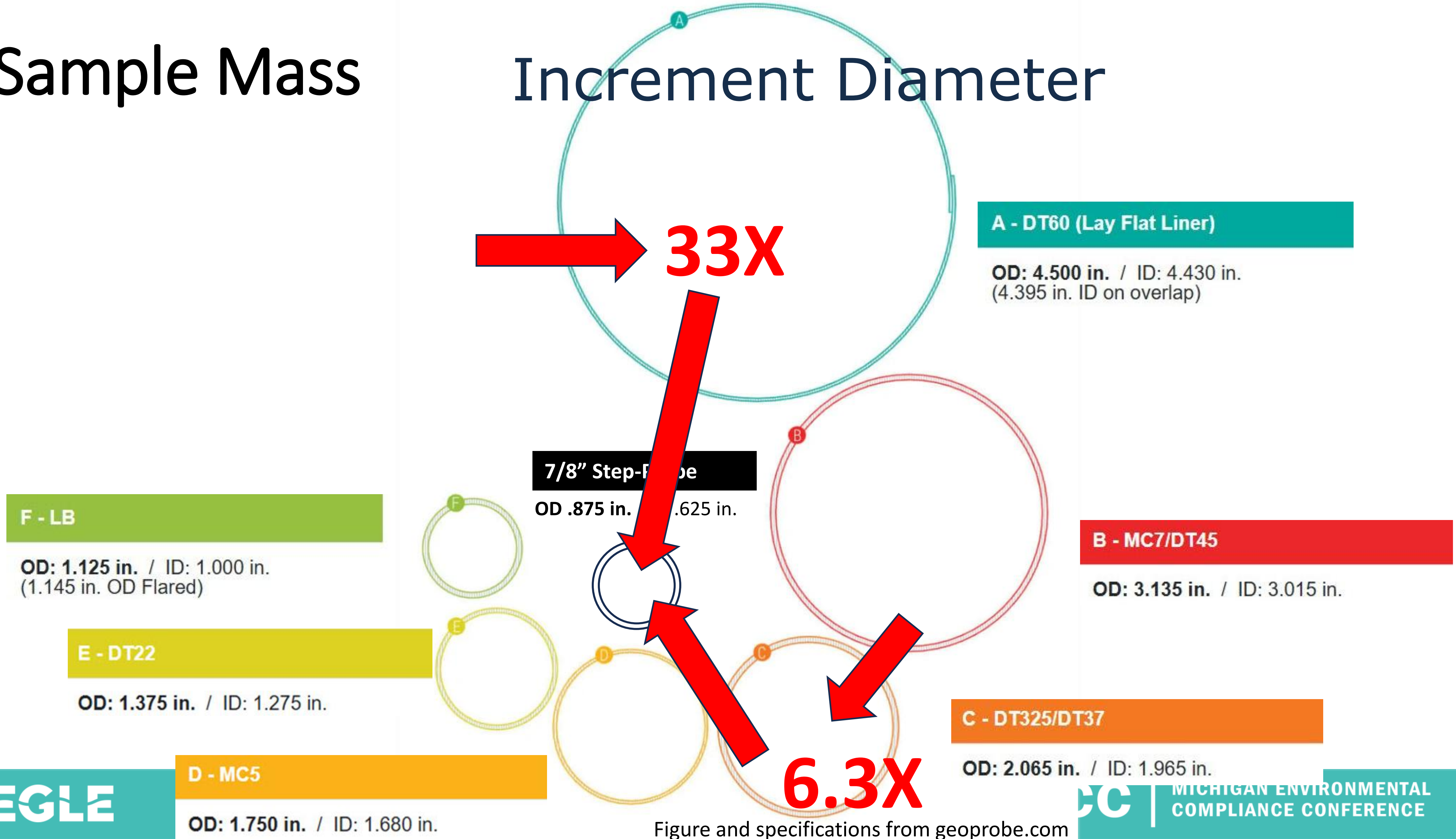


Figure and specifications from geoprobe.com

Choosing the Correct Sampler

			AMS	JMC Soil Samplers				Geoprobe Drilling Rigs & Tooling Manufacturer								
								MC5		DT-22	DT325/DT37		MC7/DT45		DT60	
			7/8-inch Step Probe	PN150 Sub-Soil Probe	PN425 Sub-Soil Probe	Original 1.0-inch GeoProbe Rods	LB Soil Sampler (9/16 only)	2.25-inch Geoprobe Liner Full	Quartered	Geoprobe Liner	Full	Quartered	Full	Quartered	Full	Quartered
Density of Soil*	0.0016	g/mm3														
Outer Diameter	OD	in	0.875	?	?	?	1.5	1.75		2.065	2.065		3.135		4.5	
Inner Diameter	ID	in	0.777	0.8	1.2	1	1	1.68		1.965	1.965		3.015		4.43	
Inner Diameter	**ID**	mm	19.7358	20.32	30.48	25.4	25.4	42.672	42.672	49.911	49.911	49.911	76.581	76.581	112.522	112.522
Length		in	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Length		mm	50.8	50.8	50.8	50.8	50.8	50.8	50.8	50.8	50.8	50.8	50.8	50.8	50.8	50.8
Volume of Increment		mm3	15539.97	16473.59	37065.57	25739.98	25739.981	72648.522	72648.522	99387.857	99387.86	99387.86	233982.2	233982.2	505144.5	505144.5
Mass of Increment		g	24.86396	26.35774	59.30492	41.18397	41.183969	116.23763	29.059409	159.02057	159.0206	39.75514	374.3715	93.59289	808.2313	202.0578
Number of Increments		#	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Mass of DU Sample		kg	1.243198	1.317887	2.965246	2.059198	2.0591985	5.8118817	1.4529704	7.9510286	7.951029	1.987757	18.71858	4.679644	40.41156	10.10289
Length		in	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Length		mm	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4	152.4
Volume of Increment		mm3	46619.92	49420.76	111196.7	77219.94	77219.942	217945.57	217945.57	298163.57	298163.6	298163.6	701946.7	701946.7	1515434	1515434
Mass of Increment		g	74.59187	79.07322	177.9147	123.5519	123.55191	348.7129	87.178226	477.06171	477.0617	119.2654	1123.115	280.7787	2424.694	606.1735
Number of Increments		#	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Mass of DU Sample		kg	3.729593	3.953661	8.895737	6.177595	6.1775954	17.435645	4.3589113	23.853086	23.85309	5.963271	56.15573	14.03893	121.2347	30.30867

* - www.aqua-calc.com

DU thickness

Every soil molecule needs to have an equal opportunity to be included in the lab sample

Increment needs to account for the entire DU thickness

Three Best Ways to do this:

- **BEST** - Entire probe diameter through the total DU thickness
- **2nd BEST** – Entire quartered probe diameter through the total DU thickness or small diameter mass reduction tool (Denstedt Tool)
- **3rd BEST**– Collect multiple plugs at intervals throughout the DU thickness (QED ComboCore, Terra Core, other 5035 samplers)

Mass Reduction In The Field

Options for larger Volume/Mass Samples

- Quartering the sample
- Splitters – Riffle, Rotary Sectoral
- Subsampling in the field (e.g. plug sampling, etc.)
- 2D Slabcake in the field
- Fractional Shoveling- Pitard 1993 – The Last Resort

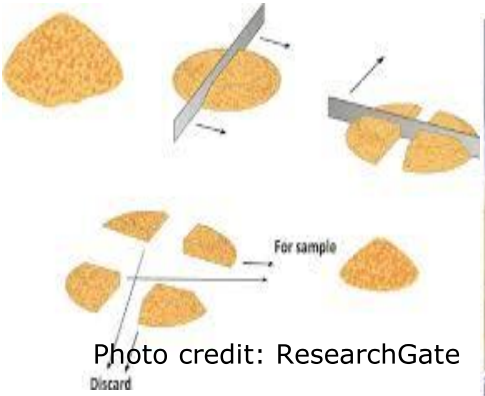


Photo credit: ResearchGate

Photo credit: ITRC

Photo credit: Gilson and Humboldt

Photo credit: ITRC

Mass Reduction in the Field

Mixing Populations of Data

Urban fill for metals and PNAs mixed with PNAs from Asphalt

Urban Fill mixed with volatile organic compounds VOCs from former Gas Station

Lead related to air deposition mixed with lead-based paint

Orchard Arsenic mixed with per- and polyfluoroalkyl substances (PFAS) from BioSolids

Soil Heterogeneity

Compositional- Variability between individual particles (soil type, grain size, shape, density)

Distributional- Variability within the DU (Contaminants)

Small Scale- what happens in the lab sample

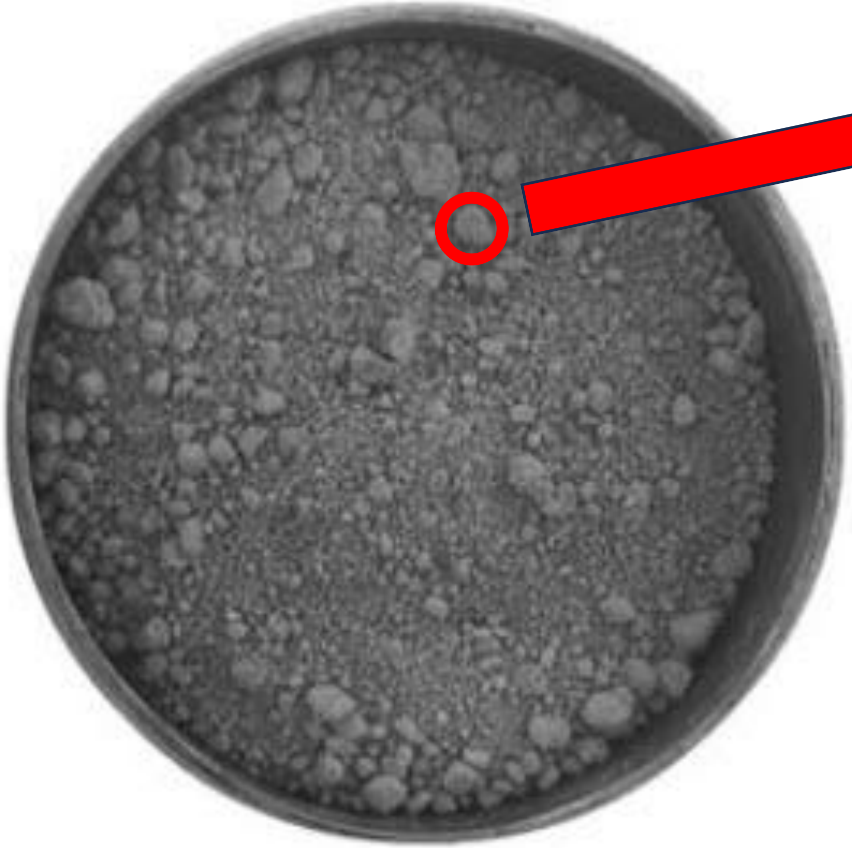
Large Scale- what happens in the field

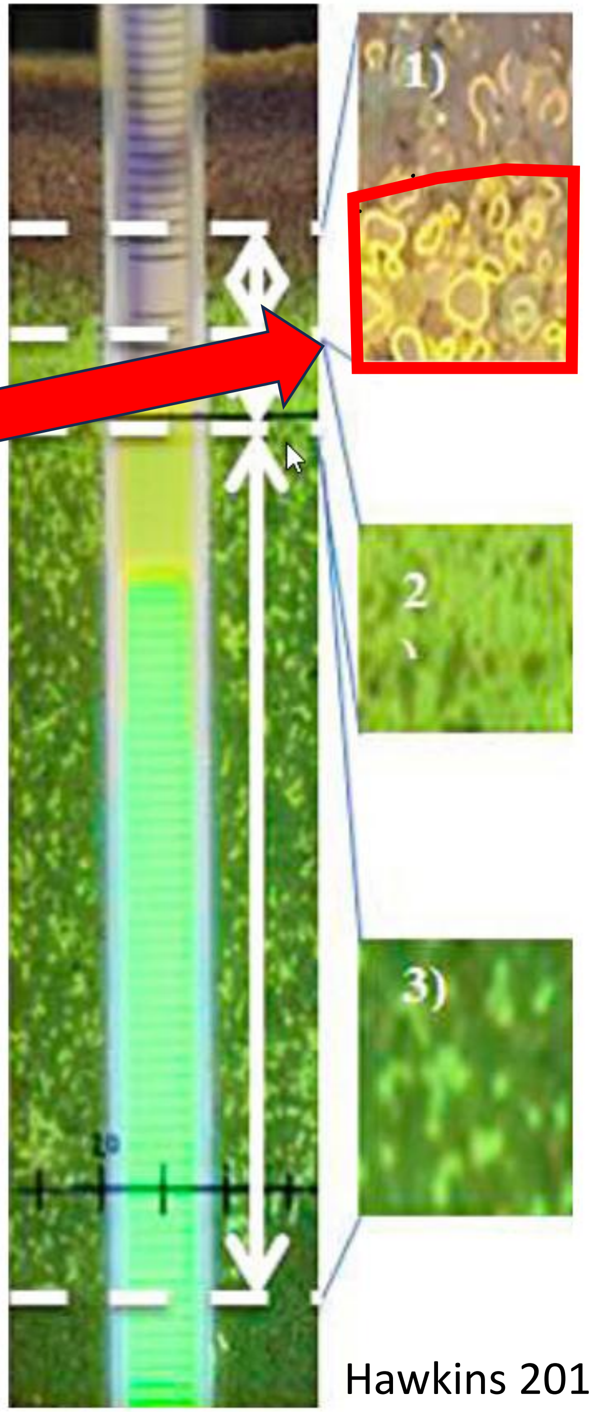
Other Heterogeneity - Temporal

"Nugget" Effect – VOCs, PNAs and PCBs

Soil Heterogeneity


(a)


(b)



Hawkins 2012

Compound Specific Heterogeneity

Both naturally occurring compounds and contaminants have their own heterogeneity.

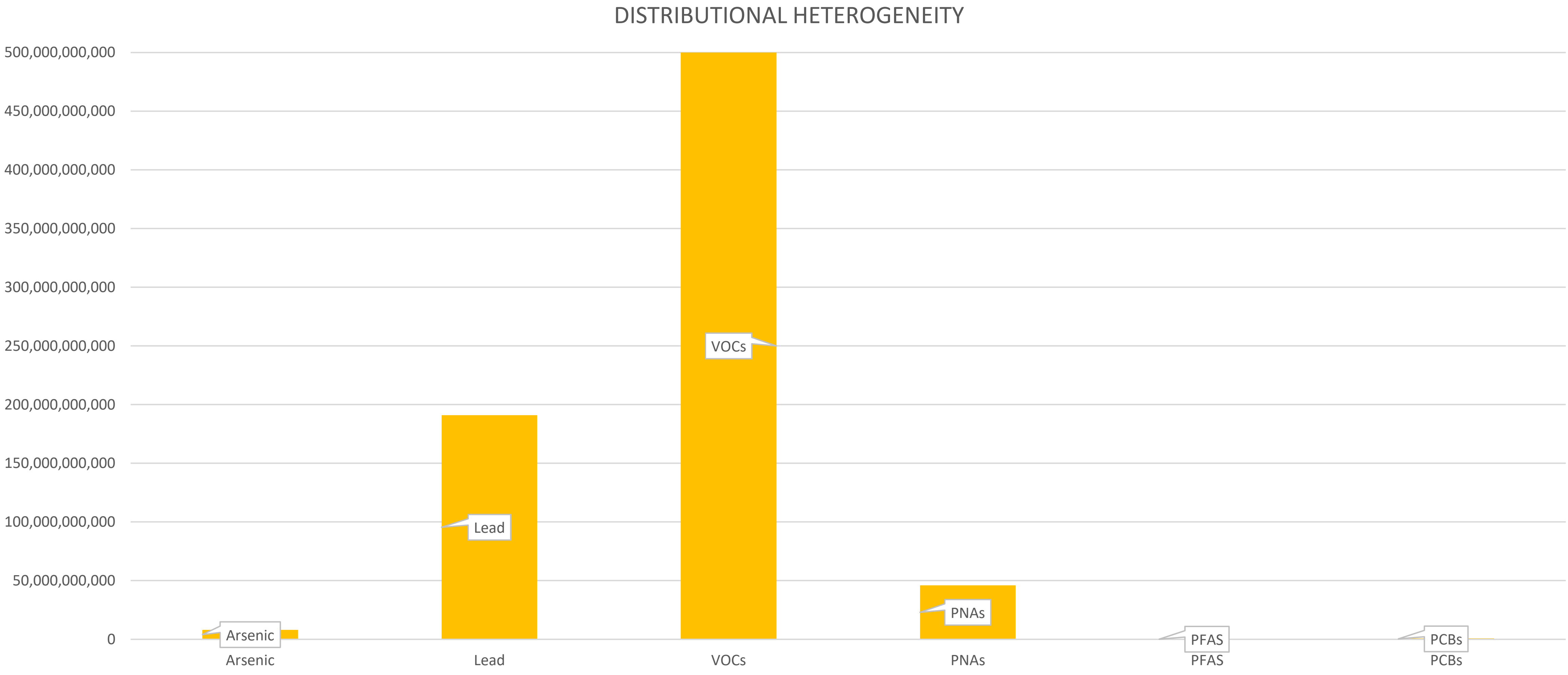
Maximum Range of concentrations from Reporting Limit (RL) to maximum (saturation)

Grainsize – Lead this is why we sometimes grind

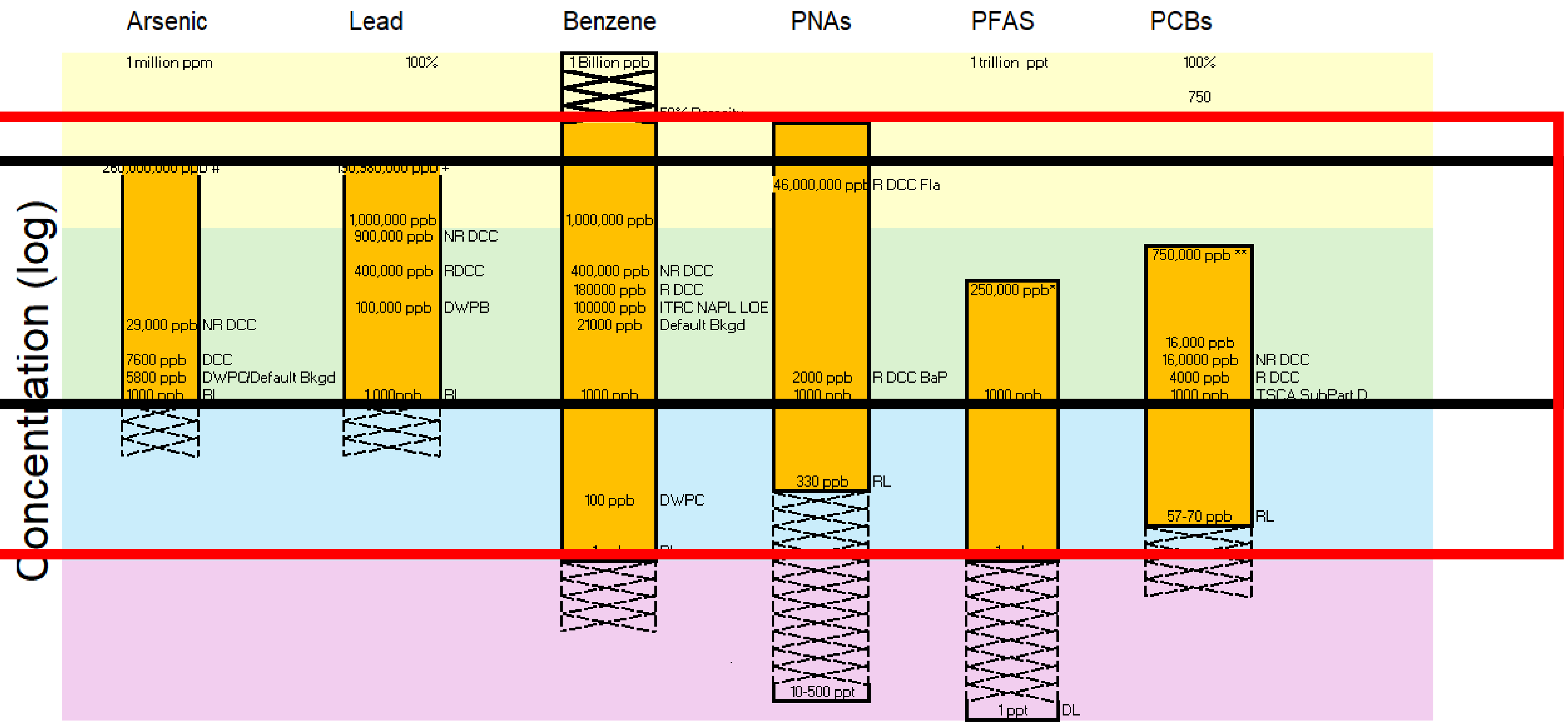
Oil/Gasoline adsorbs to soil

PFAS is attracted to organic matter

Compound Specific Heterogeneity of Soil



Compound Specific Heterogeneity of Soil



\# - *Arsenic: Medical and Biologic Effects of Environmental Pollution* , National Acadamies Press, 1977
\+ - Mousavi Seyed Majid, et. al, *Lead (Pb) Bioavailability in the Environment, it's Exposure and Effect,* Journal of Advances in Environmental Helath Research, March 2022
* - Highest concentration in soil at Wolverine, Rockford, MI per EGLE RRD records
** - EPA Superfund Site per EPA PCB Factsheet

Why Does This Matter?

A decision unit designed for Direct Contact for Lead might be appropriate for Direct Contact for Arsenic but is maybe not appropriate for:

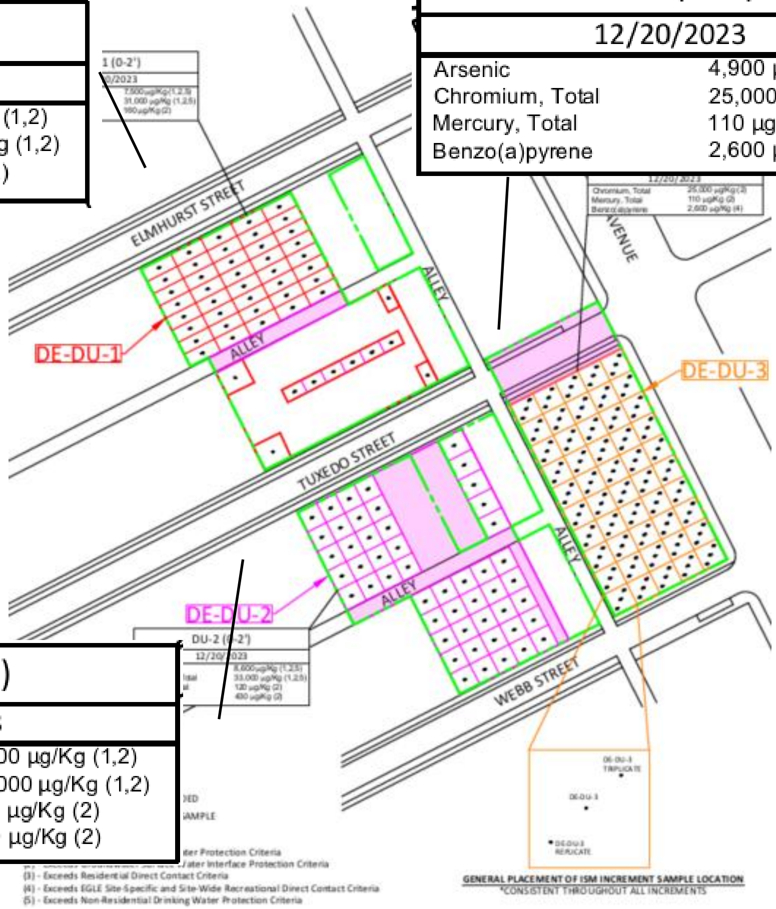
Direct Contact for PNAs or Polychlorinated Biphenyls (PCBs)

Soil Protective of Drinking Water/GSI for VOCs or PFAS

Soil Protective of Indoor Air Inhalation for chlorinated solvents (tetra- or trichloroethylene [TCE/PCE]).

Case Study: Sampling Plan

- ❖ Main Concerns
  - Urban Fill
  - The Direct Contact Pathway
- ❖ Design
  - 3 DUs
  - 0-2 ft Interval
  - 50 Increments per DU
  - 1 Triplicate QA/QC Sample
  - Equipment – Geoprobe
  - Mass Reduction via Plug Sampling Method
  - Analysis:
    - PNAs
    - PCBs
    - Michigan 10 Metals



DU-1 (0-2')	
12/20/2023	
Arsenic	7,500 µg/Kg (1,2)
Chromium, Total	31,000 µg/Kg (1,2)
Mercury, Total	160 µg/Kg (2)

DU-3 (0-2')	
12/20/2023	
Arsenic	4,900 µg/Kg (1,2)
Chromium, Total	25,000 µg/Kg (2)
Mercury, Total	110 µg/Kg (2)
Benzo(a)pyrene	2,600 µg/Kg (4)

DU-2 (0-2')	
12/20/2023	
Arsenic	8,600 µg/Kg (1,2)
Chromium, Total	33,000 µg/Kg (1,2)
Mercury, Total	120 µg/Kg (2)
Selenium	430 µg/Kg (2)

What is Reproducible Environmental Data?

Reproducible Data is a fundamental requirement of the Scientific Process

Triplicate Data 1:10 DUs per population (Might need every DU)

If a result cannot be reproduced, it's impossible to determine compliance (Not Defensible) regardless of media

Self Imposed 30% RSD is reproducible

Difficult and expensive to do with discrete samples across a large area/volume of soil

Percent Relative Standard Deviation

What is %RSD?

It's a measurement of precision. It tells you whether your data has captured the heterogeneity of the Decision Unit.

$$\%RSD = \frac{Standard\ Deviation}{Mean} X\ 100$$

Percent Relative Standard Deviation

But really what is %RSD?

- Simply it's a measurement of how spread out a population of numbers is……Reproducibility

How do you calculate?

- MS Excel – Use Sample (**STDEV.S**) not Population (STDEV.P)
  - On-line RSD Calculators – Calculator-Online.net, miniwebtool.com, Inchcalculator.com

Triplicate w/ Non-Detects "Don't Calculate %RSD"

Case Study: %RSD DATA - Metals

Parameter	Acceptable %RSD	DE-DU-3	Duplicate	Triplicate	Standard Deviation	Mean	%RSD
Arsenic	30%	4,400	4,900	4,600	252	4,633	5.43%
Barium	30%	63,000	54,000	54,000	5,196	57,000	9.12%
Cadmium	30%	380	460	340	61	393	15.53%
Chromium	30%	25,000	17,000	23,000	4,163	21,667	19.22%
Copper	30%	15,000	42,000	14,000	15,885	23,667	**67.12%**
Lead	30%	46,000	35,000	50,000	7,767	43,667	17.79%
Selenium	30%	310	260	310	29	293	9.84%
Silver	30%	ND	ND	ND	NA	NA	NA
Zinc	30%	120,000	54,000	97,000	33,501	90,333	**37.09%**
Mercury	30%	97	94	110	9	100	8.48%

ND – Not Detected
NA – Not Applicable

Case Study: %RSD DATA - PCBs

Parameter	Acceptable %RSD	DE-DU-3	Duplicate	Triplicate	Standard Deviation	Mean	%RSD
PCBs	30%	ND	ND	ND	NA	NA	NA

ND – Not Detected
NA – Not Applicable

Case Study: %RSD DATA - PNAs

Parameter	Acceptable %RSD	DE-DU-3	Duplicate	Triplicate	Standard Deviation	Mean	%RSD
Acenaphthene	30%	ND	ND	ND	NA	NA	NA
Acenaphthylene	30%	390	ND	ND	NA	NA	NA
Anthracene	30%	610	ND	ND	NA	NA	NA
Benzo(a)anthracene	30%	2,400	ND	500	NA	NA	NA
Benzo(a)pyrene	30%	2,600	ND	520	NA	NA	NA
Benzo(b)fluoranthene	30%	3,800	450	730	1,859	1,660	**111.96%**
Benzo(ghi)perylene	30%	1,400	ND	ND	NA	NA	NA
Benzo(k)fluoranthene	30%	1,300	ND	ND	NA	NA	NA
Chrysene	30%	2,500	330	500	1,207	1,110	**108.72%**
Dibenzo(a,h)anthracene	30%	430	ND	ND	NA	NA	NA
Fluoranthene	30%	4,500	660	940	2,141	2,033	**105.28%**
Fluorene	30%	ND	ND	ND	NA	NA	NA
Indeno(1,2,3-cd)pyrene	30%	1,800	ND	330	NA	NA	NA
2-Methylnaphthalene	30%	ND	ND	ND	NA	NA	NA
Naphthalene	30%	ND	ND	ND	NA	NA	NA
Phenanthrene	30%	1,600	360	430	697	797	**87.44%**
Pyrene	30%	3,800	580	830	1,791	1,737	**103.14%**

ND – Not Detected
NA – Not Applicable

Problem: What happens when you exceed your %RSD or have NDs?

It simply means that your sample is not reproducible for those compounds

Your %RSD is self imposed

The data might be reproducible enough to make your decision

Look at the Triplicate Data if triplicates have non-detects

%RSD becomes more difficult to achieve at RL

- Near Reporting Limit - Data set 1, 3, 4 – RSD 57%
- Widely Varied – PNA Data set ND<330, 1900, 2500 – RSD=71%

Case Study: Analytical Results

Parameters	Chemical Abstract Service Number	Statewide Default Background Levels	Residential Drinking Water Protection Criteria	Groundwater Surface Water Interface Protection Criteria	Residential Soil Volatilization to Indoor Air Inhalation Criteria	Residential Infinite Source Volatile Soil Inhalation Criteria	Residential Particulate Soil Inhalation Criteria	Residential Direct Contact Criteria	Decision Unit	DE-DU-1	DE-DU-2	DU-3 (Triplicate)
(Refer to detailed laboratory report for method reference data)									Value Description	ISM Analytical Results	ISM Analytical Results	ISM Analytical Results***
									Depth	0-2'	0-2'	0.5-2.5'
Metals (µg/kg)												
Arsenic (B)	7440-38-2	5,800	**4,600**	**4,600**	NLV	NLV	7.20E+05	19,000*		**7,500**	**8,600**	**4,900**
Barium (B)	7440-39-3	75,000	1.30E+06	(G)	NLV	NLV	3.30E+08	3.70E+07		100,000	69,000	63,000
Cadmium (B)	7440-43-9	1,200	6,000	(G,X)	NLV	NLV	1.70E+06	5.50E+05		610	540	460
Chromium, Total	7440-47-3	18,000 (total)	**30,000**	**3,300**	NLV	NLV	2.60E+05	2.50E+06		**31,000**	**33,000**	**25,000**
Copper (B)	7440-50-8	32,000	5.80E+06	(G)	NLV	NLV	1.30E+08	2.00E+07		33,000	39,000	42,000
Lead (B)	7439-92-1	21,000	700,000	(G,X)	NLV	NLV	1.00E+08	4.00E+05		99,000	90,000	50,000
Mercury, Total	7439-97-6	130	1,700	**50 (M); 1.2**	48,000	52,000	2.00E+07	1.60E+05		**160**	**120**	**110**
Selenium (B)	7782-49-2	410	4,000	**400**	NLV	NLV	1.30E+08	2.60E+06		350	**430**	310
Silver (B)	7440-22-4	1,000	4,500	100 (M); 27	NLV	NLV	6.70E+06	2.50E+06		<100	<100	<100
Zinc (B)	7440-66-6	47,000	2.40E+06	(G)	NLV	NLV	ID	1.70E+08		160,000	150,000	120,000
Polychlorinated Biphenyls (PCBs, µg/kg)												
PCB, Aroclor 1260	11096-82-5	NA	NA	NA	NA	NA	NA	NA		120	<100	<100
PCBs (J,T)	1336-36-3	NA	NLL	NLL	3.00E+06	2.40E+05	5.20E+06	4,000		120	BDL	BDL
Polynuclear Aromatic Hydrocarbons (PNAs, µg/kg)												
Acenaphthylene (Q)	208-96-8	NA	5,900	ID	1.60E+06	2.20E+06	2.30E+09	1.60E+06		<330	<330	390
Anthracene (Q)	120-12-7	NA	41,000	ID	1.0E+9 (D)	1.40E+09	6.70E+10	2.30E+08		<330	<330	610
Benzo(a)anthracene (Q)	56553	NA	NLL	NLL	NLV	NLV	ID	20,000		<330	340	2,400
Benzo(a)pyrene (Q)	50328	NA	NLL	NLL	NLV	NLV	1.50E+06	**920****		<330	380	**2,600**
Benzo(b)fluoranthene (Q)	205992	NA	NLL	NLL	ID	ID	ID	20,000		360	570	3,800
Benzo(g,h,i)perylene (Q)	191242	NA	NLL	NLL	NLV	NLV	8.00E+08	2.50E+06		<330	<330	1,400
Benzo(k)fluoranthene (Q)	207089	NA	NLL	NLL	NLV	NLV	ID	2.00E+05		<330	<330	1,300
Chrysene (Q)	218019	NA	NLL	NLL	ID	ID	ID	2.00E+06		<330	380	2,500
Dibenzo(a,h)anthracene (Q)	53-70-3	NA	NLL	NLL	NLV	NLV	ID	2,000		<330	<330	430
Fluoranthene	206440	NA	7.30E+05	**5,500**	1.0E+9 (D)	7.40E+08	9.30E+09	4.60E+07		460	620	4,500
Indeno(1,2,3-cd)pyrene	193395	NA	NLL	NLL	NLV	NLV	ID	20,000		<330	<330	1,800
Phenanthrene	85018	NA	56,000	**2,100**	2.80E+06	1.60E+05	6.70E+06	1.60E+06		<330	<330	1,600
Pyrene	129000	NA	4.80E+05	ID	1.0E+9 (D)	6.50E+08	6.70E+09	2.90E+07		400	570	3,800
Remaining PNAs	-	-	-	-	-	-	-	-		BDL	BDL	BDL

* Site-Specific and Site-Wide RBA-Adjusted Recreational Direct Contact Criteria Arsenic

**EGLE Site-Specific, Site-Wide Recreational Direct Contact Criteria

***Results based on highest value from triplicate sampling

Case Study: Outcome & Other Options

❖ Outcome:

- Data for most metals is reproducible
- All data is still useable
- Site-specific direct contact criteria prepared for:
  - Arsenic
  - Benzo(a)pyrene
- Response actions taken to mitigate unacceptable exposures

❖ Other Options:

- Redesign DU and resample with:
  - Smaller depth intervals
  - Smaller DU design
  - Increased increments
- Better field observation and removal of non-soil debris and/or waste materials (e.g., asphalt, rocks, brick, concrete, etc.)
- Better documentation (photos, logs, etc.)
- Timing matters

Reach Out To Us With Questions

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