# Incremental Sampling Methodology

## Evaluating Risk by Design: The Importance of Representative Sampling for Managing Environmental Risk

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**Presentation Agenda**

- Incremental Sampling Methodology (ISM) Overview
- Decision Making and Error Reduction by Design
- Development of Decision Units (DUs)
- Case Studies
- Resources and Contacts
- Q & A

**ISM Overview**

- ISM:
  - Yields *representative, reproducible,* and *defensible* data
  - Reduces sampling and laboratory error by design
  - Reduces chances of missing or underestimating significant contamination
  - Simplifies statistical analysis of data
- Investigation Objective
  - What we thought in the 1980s
  - What we know in the 2010s
- ISM provides an accurate average concentration for any constituent in a given area.
- Discrete sampling: Calculation of the average concentration from multiple samples (data interpretation)
  - Incremental sampling: Measurement of the average concentration from a single sample (direct result)
- In the world of risk assessment, the concentration term (i.e. cleanup criterion) is a reasonable estimate of the concentration of a hazardous substance that a receptor can be exposed to over time (i.e. average concentration) without adverse effect.
- Process
  - Part 1: Define Project Objectives and Develop a Sampling Plan
    - Develop Conceptual Site Model
    - Identify Potential Receptors and Exposure Pathways
    - Establish Data Quality Objectives (DQO) using a systematic planning process (i.e. U.S. EPA Seven Step DQO Process)
      - Step 1: State Problem
      - Step 2: Identify Decision
      - Step 3: Identify Decision Inputs
      - *Step 4: Define Study Boundaries*
      - Step 5: Develop Decision Rules
      - *Step 6: Specify Performance Criteria*
      - *Step 7: Optimize Design*
  - Part 2: Field Implementation
    - Select increment locations using a Systematic Random Process
    - Collect multiple (>30 to 100) increments of uniform size from the entire decision unit
    - Combine increments to yield one sample:
      - Non-volatile organic compounds (VOCs): All increments into a single 1 to 2 kilogram sample

        - VOCs: All increments (~5 to 10g each) into a single sample bottle, preserved with methanol (~1 ml MeOH/1g of sample)
    - Collecting a Non VOC Incremental Sample
    - Collecting a VOC Incremental Sample
- Part 3: Laboratory Preparation and Analysis
    - Air drying and sieving entire sample
    - Particle size reduction (grinding) of entire sample, if required by Sampling Plan.
        - Specialized grinding equipment; may not be available at all laboratories.
        - May not be appropriate in some situations, such as for malleable metals.
    - Increment sub-sampling (>30 increments) to provide representative aliquot for analysis
    - ISM Laboratory Processing is designed to ***retain representation*** of the sample collected in the field

**Decision Making and Error Reduction by Design**

- Decision Making and Error Reduction by Design: Decisions and Confidence
    - Think of:
        - the number of samples you take…
        - the size of the samples you take…
        - the mass of the samples you take……
    - Site is 1 cubic yard
        - One part in a million
            - One penny in $10,000
            - 32 seconds out of a year
            - One drop in a 10 gallon aquarium
    - Site is 1 acre and 3 feet deep
        - One part in a billion
            - One drop in a 10,000 gallon swimming pool
- Decision Making and Error Reduction by Design: Data Quality
    - Excerpt from Part 201
      *14) Approval by the department of remedial action based on the categorical standard in subsection (1)(a) or (b) shall be granted only if the pertinent criteria are satisfied in the affected media. The department shall approve the use of probabilistic or statistical methods or other scientific methods of evaluating environmental data when determining compliance with a pertinent cleanup criterion if the methods are determined by the department to be reliable, scientifically valid, and* ***best represent actual site conditions*** *and exposure potential.*
- Decision Making and Error Reduction by Design: Statistics
    - In the world of risk assessment, the concentration term (i.e. cleanup criterion) is a reasonable estimate of the concentration of a hazardous substance that a receptor can be exposed to over time (i.e. average concentration) without adverse effect.
    - ISM provides an accurate average concentration for any constituent in a given area.
        - Discrete Sampling: Calculation of the average concentration from multiple samples (data interpretation)
        - Incremental Sampling: Measurement of the average concentration from a single sample (direct result)
    - Descriptive vs. Inferential Statistics
        - Descriptive Statistics is a more ***direct*** way to quantitatively describe our data.
        - Inferential Statistics ***infers from the sample to the population*** based on the characteristics of the sample.
            - Inferential Statistics is a model based on (and limited by) what you sampled, the number of samples taken, and an ***assumed*** distribution.
            - Inferential Statistics ***assumes*** that the sample is representative of site variability.
- Decision Making and Error Reduction by Design: Determining Error
    - Use replicate sampling and data to evaluate error

        - ISM typically uses triplicate sampling to evaluate error
    - Relates to DQO *Step 6: Specify Performance Criteria (how good does my data have to be to be valid input for decision-making).*
    - Replicates (and measuring error) are most important when results are close to the decision criteria, when establishing criteria (i.e. site-specific background), or closing a site – when there is less tolerance for error or uncertainty.
    - The number of replicates depends on the DQO (Step 6)
    - The error is most often evaluated in terms of Relative Standard Deviation (RSD) (Coefficient of Variance as a %) of triplicates of specific DU(s) – this is an evaluation of the reproducibility (precision).
    - %RSD = Standard Deviation/Mean, as a %
    - Typical %RSD for ISM (DQO Step 6)
        - Lab replicates < 20%
        - Field replicates < 30%

**Development of Decision Units (DUs)**

- Proper identification of DUs is instrumental in ensuring that the data collected can be used to meet investigative goals and make the correct risk-based decision (i.e DQO).
- A DU is typically the smallest exposure area (volume), also taking into account other factors and parameters.
- Relates to DQO *Step 4: Define Study Boundaries* and *Step 7: Optimize Design*
- Factors to consider:
    - Site conditions
        - Surface Cover
        - Buildings
        - Storm Water Runoff
    - Past land uses
    - Current land uses
    - Future land uses: Known and potential
    - Zoning
    - Stakeholder needs
        - Purpose - DQO
            - Due Care
            - Characterization/Background
            - Investigation
            - Remedial Design
            - Verification/Closure/No Further Action
        - Budget
        - Schedule
- Parameters to consider:
    - Contaminant Source
    - Exposure pathways
    - Receptors
    - Chemicals of Concern
    - Site Heterogeneity
        - Soil Type(s)
        - Lithology
    - Statutory requirement
    - Remedial goals
- Example: Former Shooting Range
    - Factors:
        - Site condition: Sloped terrain, heavy vegetation
        - Current land uses: Municipal wood chip storage
        - Past land uses: Small arms shooting range

        - Layout of targets and firing line unknown
        - Primary firing direction believed to be to the north
        - Consider penetration depth
    - Future land uses: Unknown, owned by municipality, zoned industrial
  - Stakeholder needs
    - Purpose: No Further Action
  - Parameters to consider:
    - Exposure pathways: Direct Contact
    - Receptors: Workers
    - Statutory requirement: Non-Residential
    - Remedial Goal: Non-Residential Contact Criteria for Lead (900 mg/kg)

**Case Studies**

- Ford Wixom Plant
  - Data Quality Objectives (DQOs)
    - 1) State Problem: Staged soils may be contaminated
    - 2) Identify the Decision: If the staged soils exceed the appropriate criteria, the soils cannot be used as backfill.
    - 3) Identify Decision Inputs: Analytical soil concentration data, MDEQ Non-Residential Criteria
    - 4) Define Study Boundaries: 650 CY of staged soils
    - 5) Develop Decision Rule: If soil concentrations exceed Non-Residential Criteria, then the soil will be used as on-site backfill. Otherwise, soil will be transferred to an off-site disposal facility.
    - 6) Specify Performance Criteria: %RSD between replicates < 30%
    - 7) Optimize Design
      - The stockpile (650 CY) was considered one DU.
      - Fifty (50) increments were collected; one (1) increment per approximately every seven (7) bucket loads.
      - Triplicate samples were collected to assess the precision of the data.
      - Samples were analyzed for VOCs, PNAs, PCBs, and metals
      - Analytical data compared to Non-Residential Criteria
  - Results and Outcome
    - Analytical data identified concentrations were below Non-Residential Criteria for all analyzed constituents.
    - %RSD < 14%
    - Sample results were compared to Part 201 Cleanup Criteria and regional background concentrations as applicable. Concentrations did not exceed Non-Residential Criteria in the DU.
    - The stockpile material will be used for backfill as needed.
- Case Studies: The Mines Golf Course
  - DQO
    - 1. State the Problem: Arsenic levels in soils may exceed the MDEQ Direct Contact Criteria for Arsenic.
    - 2. Identify the Decision: If surface soils pose an unacceptable risk to users, then additional work will be needed for approval of the Documentation of Due Care Compliance (DDCC).
    - 3. Identify Decision Inputs: Soil analytical data
    - 4. Define Study Boundaries: The portion of the golf course that was formerly orchard.
    - 5. Develop Decision Rules
      - If mean value for Arsenic is > Non-Residential DCC, additional work will be needed for approval of the DDCC.
      - If < Non-Residential DCC but > Residential DCC, approve DDCC with controls for residential trespass.
      - If < Residential DCC, the site is no longer a facility.

        - 6. Specify Performance Criteria: %RSD between replicates < 30%
        - 7. Optimize Design
            - ISM will be used to estimate the average concentration of Arsenic in surface soils.
            - 30 increments will be collected in each DU to produce a sample.
            - Increment locations will be selected using a systematic random process.
            - Triplicate samples will be collected in one DU (DU #3) to estimate precision (%RSD).
    - Performance Criteria: %RSD ≤ 30
        - Discrete Sampling
            - No replicates sampled
            - %RSD for discrete samples = 82.9%
        - ISM
            - Triplicate samples collected from DU #3
                - Original: sample: 9.2 mg/kg
                - Duplicate Sample: 11 mg/kg
                - Triplicate Sample: 8.5 mg/kg
        - % RSD = 13.5%
    - Outcome
        - The DDCC Plan was approved with additional signage and a clear visual natural demarcation of the boundary between the golf course and the adjacent residential properties.
        - A Restrictive Covenant was placed on the property restricting site use to commercial or industrial uses, as well as restricting commercial uses that could result in a "residential type exposure" such as educational uses, parks, community gardens, outdoor athletic fields, playgrounds, and zoos.
        - The No Further Action Report was approved.
- Case Studies: Orchardview Property
    - DQO
        - 1) State Problem: Does Arsenic-impacted soil from a former orchard pose a risk for redevelopment of the property for residential housing?
        - 2) Identify Decision: Is any risk mitigation needed prior to redevelopment, to address any potential direct contact hazards to future residents, due to former use as an orchard?
        - 3) Identify Decision Inputs: Soil analytical data
        - 4) Define Study Boundary: Historical orchard, approximately 9.38 acres
        - 5) Develop Decision Rules:
            - If the average soil concentration of arsenic in any exposure DU is > Residential Direct Contact Criterion (RDCC) for Arsenic, then there is a potential hazard to future residents and appropriate exposure controls or other risk mitigation measure(s) would be required prior to redevelopment.
            - If the average concentration of Arsenic in any exposure DU is < RDCC, then the soil in the exposure DU does not pose a hazard and no response activity is required.

        - 6) Specify Performance Criteria: % RSD ≤ 30 for triplicates
        - 7) Optimize Design
            - Approximate ¼ acre DUs designated for the residential portions of the Property
            - Other DU sizes based on uses such as a children's play area and a storm water retention pond.
            - ISM samples collected from 0-6 and 6-12 inches in each DU area (i.e. separate upper and lower DUs)
            - Approximately 50 increments/DU
            - Three sets of triplicate samples
    - Results and Outcome
        - Check Performance Criteria: Triplicate data
            - % RSD = 7.9%

        - % RSD = 3.7%
        - % RSD = 7.9%
    - Discrete sampling underestimated Arsenic concentrations:
        - In areas previously considered homogeneous (historical pesticide spray areas), discrete sampling can underestimate concentrations.
        - Samples from five of the eight DUs that were previously designated as "clean" using discrete sampling actually exceeded RDCC for Arsenic. Two other DU samples were at or just below the Arsenic RDCC.
    - The Traverse City Housing Commission was able to use the ISM data to defend their decision to move forward with their Phase II construction project and make remedial and redevelopment decisions with confidence.

**Resources and Contacts**

- Resources
    - DEQ – RRD Incremental Sampling Methodology and Applications Draft Resource Materials www.michigan.gov/documents/deq/deq-rrd-IncrementalSamplingReference-3-26-2015_485537_7.pdf
    - Interstate Technology Regulatory Council (ITRC) Incremental Sampling Methodology (2012) www.itrcweb.org/ism-1/
- DEQ Points of Contact
    - John Bradley, Superfund
    - Matt Baltusis, Superfund
    - Joe DeGrazia, SE Michigan
    - Sheryl Doxtader, Jackson
    - Bill Harmon, Superfund
    - Paul Knoerr, Grand Rapids
    - Alisa Lindsay, Kalamazoo
    - Kirby Shane, DEQ Lab
    - Dave Slayton, Hazardous Waste
    - Rebecca Taylor, Lansing
    - John Vanderhoof, Cadillac
    - Joe Walczak, Superfund
    - Eric Wildfang, Toxicology
    - Patricia Williams, Saginaw Bay
    - LEPC Authority

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**Notes:**