Human Health and Ecological Risk Assessment with Spatial Analysis and Decision Assistance (SADA) Freeware

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**Human and Ecological Risk Functions**

SADA implements EPA methods for conducting ecological and human health risk assessments
Calculation of site-specific preliminary remediation goals
Benchmark database for contaminant effects on ecological receptors
Exposure modeling for humans and over 20 other terrestrial species
Contains IRIS/HEAST toxicity databases for calculating risk from exposure
Contains EPA default exposure parameters for the risk models
Tabular screening and risk results
Point screens
Risk and dose mapping
Sample Laboratory Data

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Or transport model output files

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Data Formats

SADA can accept data in two formats: comma delimited files (csv) and Microsoft Access.
Requires the presence of certain fields in the data set.
- Easting
- Northing
- Depth
- Value
- Name
Can use other forms of information as well
- Media
- Detection
- Date
- CAS Number
Any other form of meta data can be imported as well. User can plot and retrieve this meta data during an analysis.
SADA recognizes soil, sediment, surfacewater, groundwater, air, biota, and background, and the “basic” media type. Basic is assigned to data that have no media type.
Data!

Risk Assessments are data driven:

as quality and confidence in data increases, then
so does the quality and confidence in risk estimates.

SADA offers reliable and effective data storage, visual analysis, and synthesis that can enhance risk assessments. But ultimately, the quality of the risk assessment is dependent upon the quality and quantity of the data.
Scaleable interface

Analysis Box  Data Type Box  Data Name Box  Labels Box  Layers Box

Interviews

Steps Window  Parameters Window  Results Window

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Basic Data Exploration

Data/GIS Visualization

Data Screening

Spatial Aggregation

3D visualization

Statistics

Spatial Data Query

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Classical Statistics

EPA DQO/DQA
Numerous univariate statistics
Non-parametric hypothesis testing
Power curve based sample sizes
Histograms and CDFs
Human Health Risk

SADA implements EPA methods for conducting human health risk assessments
Calculation of site-specific preliminary remediation goals
Exposure modeling for humans for five different land use scenarios
Contains IRIS/HEAST toxicity databases for calculating risk from exposure
Contains EPA default exposure parameters for the risk models
Tabular screening and risk results
Point screens
Risk and dose mapping
**SADA Human Health Functionality**

Setting Up Human Health  
Viewing Scenario Parameters  
Viewing Toxicological Parameters  
Changing Target Risk/Hazard Index  
Setting Screening and Exposure Statistics  
PRG Tables  
PRG Screen Tables  
Risk Tables  
Spatial PRG Screens  
Point Risk Maps  
Rematching a Single Contaminant
Setup Human Health

After a SADA file is created
Imports toxicity and exposure data to the SADA file
Link contaminants in toxicity file to those in SADA file
Human Health Risk Inputs

Media Data: Soil, Sediment, Surface Water, Groundwater

Exposure Scenarios: Residential, Industrial, Recreational, Agricultural, Excavation

Exposure Pathways: Ingestion, Inhalation, Dermal Contact, Food Chain (Beef, Milk, and Vegetable Ingestion)

IRIS and HEAST Toxicity Databases for Carcinogenic and Noncarcinogenic Effects

Physical Parameters for Modeling: Bioaccumulation Factors, Volatilization, Particulate Emission Factors, Permeability Constants, Absorption Factors, Saturation Coefficients, etc.
**Standard Steps of a Risk Assessment**

1. Data Evaluation
2. Exposure Assessment
3. Toxicity Assessment
4. Risk Characterization
5. Remediation
Risk Assessment - Exposure
Exposure - Conceptual Site Model

Site Conceptual Model For site A

Primary Source → Primary Release Mechanism → Secondary Source → Secondary Release Mechanism → Exposure Media → Potential Receptors and Exposure Routes & Pathways

Future Residential
- Ingestion
- Dermal Contact
- Inhalation of Volatiles

Incidental Inhalation
- Inhalation of Particulates
- Dermal Contact
- External Exposure

Consumption

Future Residential
- Ingestion
- Dermal Contact
- Inhalation of Volatiles

Incidental Inhalation
- Inhalation of Particulates
- Dermal Contact
- External Exposure

Consumption

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**Risk Characterization**

Risk Characterization
- Risk Characterization incorporates the outcomes of the previous activities (Data Evaluation, Exposure Assessment, and Toxicity Assessment) and calculates the risk or hazard resulting from potential exposure to chemicals via the pathways and routes of exposure determined appropriate for a site.

Calculate risks by media and land-use
- Quantify risk for each chemical
- Quantify risks from multiple chemicals
- Combine risks across exposure pathways
- Assess uncertainty

Identify chemicals, media, and land-uses of concern and support development of cleanup goals

We have now selected the data to be used in the risk assessment (through screening); we have selected the exposure routes and pathways (in the exposure assessment); and we have selected the appropriate toxicity values.

All of this previous information will now be used in the risk characterization step.

We are now ready to perform the forward calculations of the risk and hazard equations. Please note that the PRG determinations have been backwards (extrapolating from a set risk or hazard levels BACK to a “safe” or “acceptable” residual concentration level for a specific medium [groundwater or soil]).

In the forward calculations, we will determine the risk from each of the chemicals within each pathway. The RAIS does not calculate the total risk or hazard values in the forward direction (needed in the backward direction, though).

As appropriate, you can then sum the risks from the different chemicals within each pathway and across the pathways to determine pathway and scenario total risk and hazard values.

Note: EPA’s default assumption is one of additivity for risk and hazard values. However, there are chemicals that act together in non-additive manners, i.e. synergistic or antagonistic (PICK SOME GOOD EXAMPLES FOR EACH).

For more help, you can look at the online tutorial.
Human Health Risk Outputs

PRG Calculation

PRG Screens

Forward Risk

Risk Based Spatial Screens

Risk Mapping

Residential, Industrial, Agricultural, Recreational, Workers
Ingestion, Inhalation, Dermal, External, Food Chain
Soil, Sediment, Surfacewater, Groundwater
Packaged with Editable Scenario Parameters
Packaged with IRIS and HEAST Database
**Exposure Statistics**

Default values are maximum detected value for screening calculations and lesser of the maximum detected value and the UCL95 for exposure calculations.

User can change the approach:
- **Maximum Value**: the maximum concentration, detected or nondetected, for normal or lognormal distribution
- **Maximum Detected Value**: the maximum detected concentration for normal or lognormal distribution
- **UCL95**: the 95% upper confidence limit on the mean for normal or lognormal distribution
- **Mean**: the average concentration over all values for normal or lognormal distribution
Help File and Users’ Manual

Extensive documentation of human health methods and parameters in SADA help file

320 page user guide available from:
http://www.tiem.utk.edu/~sada/SADA_4_1_Usersguide.pdf
**Current limitations for Human Health Risk**

- ProUCL95 (confidence limits, automatic distribution testing)
- Additional tox info, target organs
- RAGS Part D reporting format
- Screening PRGs as benchmarks
- Air, dermal modifications
- Uncertainty analysis
Ecological Capabilities in SADA

SADA implements EPA methods for conducting ecological risk assessments
Benchmark database for contaminant effects on ecological receptors
Exposure modeling for over 20 other terrestrial species
Contains EPA default exposure parameters for the risk models where available
Tabular screening and risk results
Point screens
Risk and dose mapping
Ecological Functionality

Setting Up Ecological Risk
Ecological Risk Assessment Procedure
Setting Physical Parameters
Description of Ecological Benchmark Database
Histograms of Benchmark Values
Tables of Benchmark Values
Setting Screening and Exposure Statistics
Area Result Tables (Screens, Ratios)
Map Result Values (Screens, Ratios)
Rematching a Single Contaminant
Checking Ecological Version
Terrestrial Dose Modeling
Setup Ecological Risk

Identify source benchmarks database
Match contaminants in data to benchmark contaminants
Adds ecological information to SADA file

Make sure that the units on your data are mg/L for surface water and mg/kg for other media. Do you want to continue?

Yes  No
Hazard v. Risk Assessment

Ecological Hazard Assessment- a comparison of an environmental concentration to an estimated toxic threshold for a particular contaminant
- most common method for examining effects of chemicals in environment
- comparison of environmental exposure concentration to a toxic threshold (benchmark)
- iterative (or tiered) implementation
- number of toxicity data sets for soil, sediment, and surface water available for screening

Ecological Risk Assessment- explicitly attempts to estimate the probability and magnitude of the effects of exposure to contamination
Benchmark Screening

Media-specific concentration benchmarks
Choice of statistics (max, percentile, UCL95, etc.)
Hierarchy of media-specific benchmarks for screening
Spatial and tabular display of ratios
Derivation of Benchmarks:
  Toxicity testing (acute or chronic)
    - regression of concentration-response data
    - hypothesis testing
  Extrapolation from another benchmark
  Simulation of an assessment endpoint
Ecological Benchmark Screening

Suitable for screening ERAs

Compilation of ecological benchmarks for surface water (14), soil (11), sediment (17), and biota (8)

Benchmarks a function of environmental variables where appropriate

Choice of statistics (max, percentile, UCL95, etc.)

Hierarchy of media-specific benchmarks for screening

Spatial and tabular display of ratios
Map Result Screens and Ratios

Screens concentration against benchmarks at each sample location
Places a box around locations that exceed benchmark
Can use one benchmark source or establish a site-specific hierarchy
SADA Terrestrial Dose Modeling

SADA calculates dose (mg/kg BW d) from food ingestion, soil ingestion, dermal contact, and inhalation for terrestrial exposures as well as total dose summed over all pathways selected.

SSL, Female, Male, or Juvenile

Number of different species

Use a polygon to identify home range

Select species/sex

Click exposure pathways

Returns dose in mg/kg/day for each exposure pathway
Calculate Exposure for Home Range

Use a polygon to identify home range
Select species/sex
Click exposure pathways
Returns dose in mg/kg/day for each exposure pathway
**SADA Ecological Risk Needs**

Additional benchmarks
Radionuclide benchmarks and dose assessment methods
Terrestrial movement and habitat models
Eco PRG tables/calculations
Aquatic dose models
Uncertainty for dose assessment
**Spatially Explicit Ecological RA**

Use spatial distribution of contamination with dynamic movement models that also incorporate:
- Habitat quality
- Foraging behavior
- Ecological interactions

Number of movement models available in the literature
Terrestrial Movement Models
(in development)
**Spatial Risk Assessment**

Conventional Risk Assessment Limitations

Typically regulatory exposure assessment guidance recommends a summary statistic for the exposure concentration

Spatial information is lost when a summary statistic is used in the RA- exposure is assumed to be continuous in space and time

Often this lost info not recovered in the rest of the assessment/remediation process
**Spatial Risk Assessment**

Reasons for incorporating spatial statistics into risk assessment

Maximize the use of limited resources
- Efficiently collect data
- Retain collected spatial info in the risk assessment
- Use all types of available data, including expert judgment

To more adequately characterize the exposure distribution
- Extrapolate from known data to cover data gaps
- Account for spatial processes related to exposure
- Better understand uncertainties in the exposure assessment

Efficient (selective) determination of areas in need of remediation
Selective Remediation

Process that achieves a local- and/or site-specific concentration level while minimizing cleanup volume.

Implementation requires:
- data
- spatial interpolation model
- decision-maker cleanup criteria
- spatial scale inputs

Results in a spatially explicit remedial design
**Spatial Estimation**

The estimated value $V_o$ at all unsampled grid locations is estimated as a weighted average of nearby values.

$$L' = \sum_{i=1}^{N} w_i L'_i$$

![Diagram showing search neighborhood and unsampled point](image)
Determining Areas of Concern

Map of interpolated concentration values can be compared to ecological or human health risk criteria to develop areas of concern.

SADA reports area or volume of exceedance and coordinates or areal extent.
SADA web site

http://www.tiem.utk.edu/~sada/
Or just google “SADA” to freely download program and documentation.
Questions?

Comments?

This presentation has been reviewed in accordance with the U.S. Environmental Protection Agency’s peer and administrative review policies and approved for presentation. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.
Case Studies and Additional Slides

Marino Brothers Scrap Yard, Rochester Borough, Pennsylvania

Navy TCE Plume, Lemoore Naval Air Station, Lemoore, California

Small Arms Range, Tacoma, Washington

Barker Chemical Company, Inglis, Florida
- manuscript in review- Environmental Modeling and Assessment
Use of SADA Software at David Witherspoon Inc. 901 Site

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Use of SADA Software at David Witherspoon Inc. 901 Site

Spatial Analysis and Decision Assistance (SADA) software was used as the primary risk assessment/spatial assessment tool.

Operations at the site resulted in widespread radionuclide and other hazardous substances.

Shut down in 1993

Contaminated Soil, Sediment, Groundwater and Surface Water

10.5 acre site

Brief site description
## Use of SADA Software at David Witherspoon Inc. 901 Site

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<th>Things SADA can do</th>
<th>Things we used SADA for</th>
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<td>Site Characterization</td>
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<td>Geospatial Analysis</td>
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<td>Statistical Analysis</td>
<td>Risk Assessment</td>
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<td>Cost/Benefit Analysis</td>
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<td>Sample Design</td>
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<tr>
<td>Decision Analysis</td>
<td>Data Screening</td>
</tr>
</tbody>
</table>
A picture of all soil borings.
Use of SADA Software at David Witherspoon Inc. 901 Site

Point risk map of surface soil
Contoured risk. (each contaminant modeled separately).
Use of SADA Software at David Witherspoon Inc. 901 Site

Where to dig to meet risk goal. Remove 1 ft on whole site and then determine various depths
Use of SADA Software at David Witherspoon Inc. 901 Site

Block scale on left. Site scale on right. Notice no actual data points.
Use of SADA Software at David Witherspoon Inc. 901 Site

Tools in SADA that were useful
- Overburden
- Benching Angles
- Selection of Interpolation Models
- Volume Calculations
- Reproducibility for changes at meetings
- Auto documentation
- Dynamics of Risk Library
- Site Scale versus Block Scale
Use of SADA Software at David Witherspoon Inc. 901 Site

Predicted excavation depth was right on. Notice the color change. Foundry sand
Note the slag. Not predicted well at all. 15 ft deep trench.
Use of SADA Software at David Witherspoon Inc. 901 Site

Candora rd.
Use of SADA Software at David Witherspoon Inc. 901 Site

Back to Candora rd
Use of SADA Software at David Witherspoon Inc. 901 Site

Top to bottom
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