EnviroInfo 2005 (Brno)
Informatics for Environmental Protection - Networking Environmental Information
Copyright © Masaryk University Brno, Brno 2005. ISBN: 80-210-3780-6

Integrating Hazard Data with Visualization Approaches to Frame Decisions on Water Use

Margaret MacDonell[1] and Ken Morgan[2]

1. Geospatial Visualization Techniques

The effective integration of geospatial data is fundamental to making sound environmental decisions. Geographic information system (GIS) approaches are routinely incorporated into projects that require the entry, management, analysis, and display of geographic information and spatial data. Combining GIS with enhanced visualization techniques further strengthens the utility of these tools to support environmental programs. For example, the emerging field of geospatial visualization (GVis) has been tapped to evaluate issues ranging from the availability and quality of natural resources to statistical relationships among analytical data and the effectiveness of remediation programs. Visualization approaches enhance the broad presentation of scientific information that underlies decisions at multiple scales, through essentially all subfields of geospatial data management.

Key categories of GVis techniques include:

1. Data visualization — charts, two-dimensional (2-D) plots, imagery and 3-D diagrams to show interactions and animations of changing map data; this also includes flythroughs.
2. Landscape visualization and simulation — 3-D terrain (geographic) data for simulations of surface and subsurface modeling data.
3. Visual reality — 3-D and Virtual Reality Modeling Language (VMRL).
4. Web 3-D — interactive internet-enabled maps and QuickTime Virtual Reality (QTVR) for zoom and shift on the fly, over the web.

The introduction of 3-D graphics, simulation, and reality mapping into GIS for environmental decisions has fostered new expectations. For example, GVis has been heralded as a persuasive tool for city planners, designers, and traffic engineers to bring abstract project variables like visual impact analysis into the cost-benefit equation for smart urban planning. The potential clearly exists for sophisticated geospatial data analyses across a variety of applications, including to guide decisions for an essential and increasingly limited resource: water.

2. Assessing Contaminant Hazards for Water

Evaluating the sufficiency of water resources to satisfy multiple needs is a key element of environmental planning not only at the local and regional level but also at the national and international scale. The quality of potable water has emerged as a priority concern as demands increase and the availability of

---

[1] Argonne National Laboratory, Environmental Assessment Division, Building 900, 9700 S. Cass Ave., Argonne, IL 60439 ; email: macdonell@anl.gov.

[2] Texas Christian University, College of Science and Engineering (Associate Dean), TCU Box 298960, Fort Worth, TX 76129; email: k.morgan@tcu.edu.

pristine sources diminishes. Rivers, lakes, reservoirs, and groundwaters that serve as source waters for potable supplies can all be affected by human activities. These extend from sanitation and agricultural practices (which can introduce pathogens, fertilizers, and pesticides) to routine industrial practices (which involve effluents from stacks and pipes and runoff from waste disposal areas). Surface releases pose the main concern for near-term effects because attenuation processes during leaching can delay and mitigate impacts to groundwater. The quality of water supplies can also be affected by accidental releases, with potentially tragic consequences depending on the amounts released and associated exposure levels.

Thus, in addition to regularly testing drinking water supplies against limits established for common contaminants, hazard assessments are also being conducted to support preparedness planning for non-routine releases. These assessments involve identifying contaminants that could be introduced to potable water (including toxic industrial chemicals and pathogens) and characterizing dose-response information for acute and short-term oral exposures. For example, general pesticides that might be released include arsenicals, carbamates (such as aldicarb) and organophosphates (such as parathion), in addition to the rodenticide/pesticide fluoroacetate salts, and the fungicide mercuric chloride. Ammonia from fertilizers is also a possible threat at higher concentrations, as is chlorine used to disinfect water supplies. An example of how toxicity data can be organized for a given chemical is illustrated in Table 1. Matrices that combine data from multiple studies (and various species) can then be integrated to support the identification of contaminant-specific concentrations in water that might be harmful.

Study Group	Exposure Type	Duration, Dosing Regimen	Study Doses *(mg/kg-d)*	Dose for Key Effect *(mg/kg-d)*	Effect Category	Effect Description
480 rats (Sprague-Dawley), 60/gender/ dose	dietary	26 months, daily	0, 0.02, 0.21, 2.21 for males	0.02	no observed adverse effect level (NOAEL)	*(none)*
				0.21	lowest observed adverse effect level (LOAEL)	decreased hematocrit erythrocyte cholinesterase activity (to 11%)
		28 months, daily	0, 0.03, 0.29, 3.34 for females	0.03	NOAEL	*(none)*
				0.29	LOAEL	as for LOAEL above

Tab. 1: Example Summary of an Oral Toxicity Study for an Organophosphate Pesticide
Source: summarized from data in U.S. Environmental Protection Agency (EPA) (1999)

3. Integrating Data to Guide Water Use

Depending on its inherent toxicity, the amount released, and the receiving volume, if a given chemical (or chemicals) were introduced to a water supply and people were exposed, adverse health effects might result. Thus, it is important to understand at what point health effects might begin to be observed and where these could transition from mild, reversible to serious and irreversible or severe (possibly fatal) effects. This information can be used to determine when it is alright for people to drink the water, and when use should be restricted (e.g., for irrigation, laundering, washing, bathing, or cooking).

Building from the summary toxicity matrix and considering only ingestion, thresholds for adults can be calculated by converting key doses to drinking water concentrations (e.g., multiplying by a representative 70 kg and dividing by an example intake of 2 L/d). Data from the toxicity matrices can also be converted to concentration-effect plots to integrate information from multiple studies. In addition, a visual approach can be applied to represent key effects across multiple chemicals, as illustrated in Figure 1. Such displays can provide a starting point for evaluating joint toxicity.

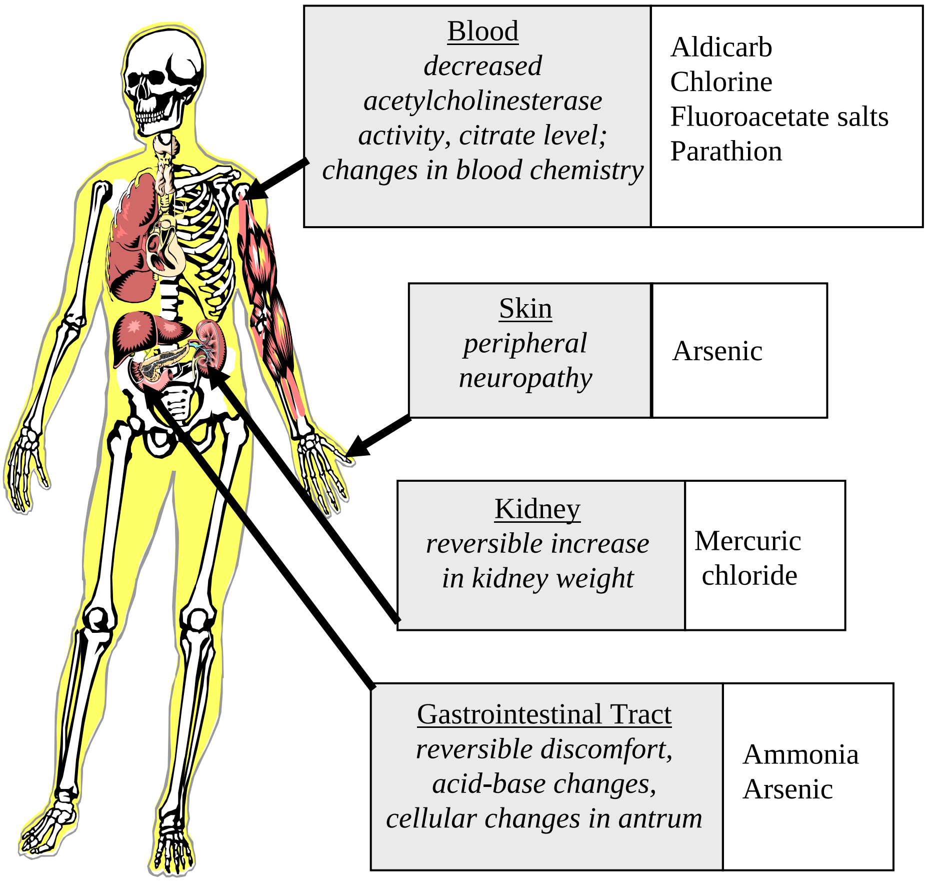

Fig. 1: Key Target Organs/Systems and Initial Effects for Selected Oral Exposures
Source: modified from MacDonell (2005)

4. Discussion

For source waters or drinking water systems that could be adversely impacted by a contaminant release, GVis can be applied to define time-integrated concentration contours that depict actual or hypothetical measurements (e.g., from preparedness exercises). These contours can then be combined with GIS data and overlain with health-based exposure targets corresponding to graded effect severities, to identify locations warranting use restrictions. Spatial representation of population characteristics (e.g., as voluntarily reported to support emergency response) can help guide tailored exposure controls. For example, these data can be integrated to produce warning triggers for sensitive subgroups, such as children for organophosphates or dialysis patients for metals. Multiple-media contaminant releases can also be assessed with linked contours as illustrated in Figure 2, using the same approach to combine these plots with toxicity-based thresholds for related exposures beyond water ingestion.

Developing target toxicity thresholds and integrated data evaluation systems in coordination with organizations responsible for consequence management can help ensure that relevant scientific information is reflected in practical responses if a release occurs. It is helpful to establish this analytic-deliberative process in advance rather than reacting when community concerns are high and risk perceptions could drive poorly informed decisions.

Visualization tools can also help identify detection gaps by linking toxicity thresholds with taste and odor thresholds. This comparison not only suggests where improved detection capabilities may be useful, it also identifies contaminants for which enhancements are not indicated because they can be detected naturally before concentrations reach levels of significant concern. In addition to framing practical research activities, the proactive development of operational advisories with visualization techniques can create a valuable resource for effective communication to guide health protection measures before, during, and after contamination events.

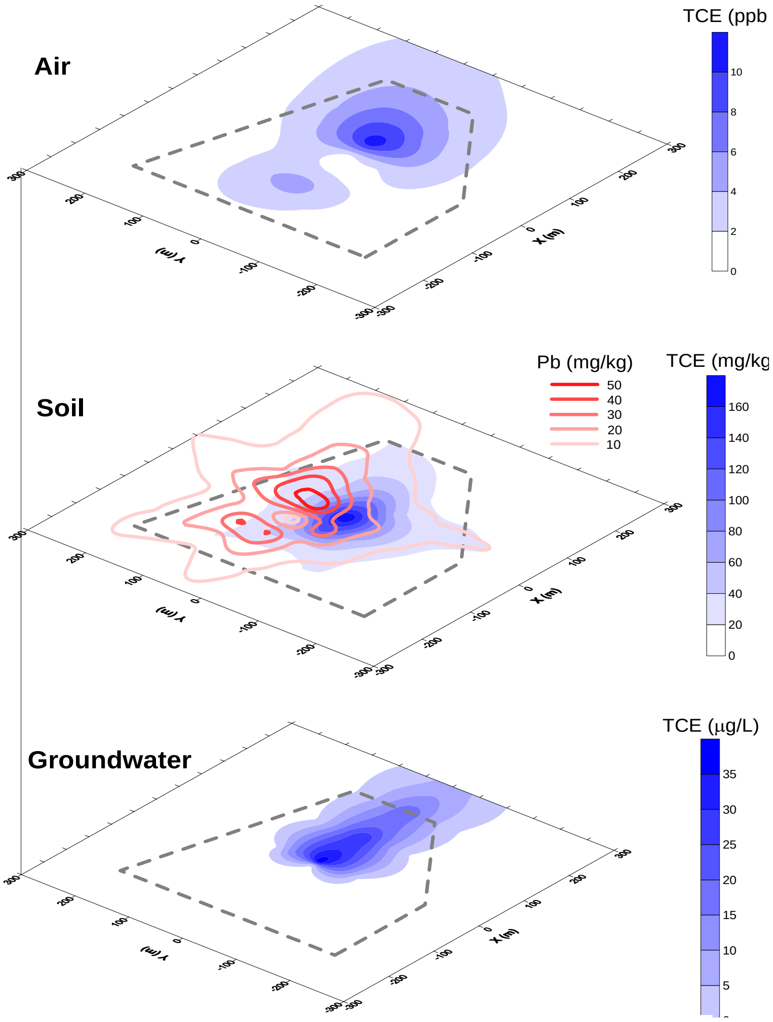

Fig. 2: Concentration Contours of Multi-Media Contamination Source: Chang (2004)

Bibliography

Chang, Y.S. (2004): personal communication from Y.S. Chang (Argonne National Laboratory, Argonne, IL) to M. MacDonell (Argonne National Laboratory, Argonne, IL), March

EPA (1999): Human Health Risk Assessment: Methyl Parathion. Office of Pesticide Programs, Health Effects Division, Washington DC, www.epa.gov/pesticides/op/methyl_parathion/mp_hed_rra.pdf

MacDonell, M. (2005): personal communication from M. MacDonell (Argonne National Laboratory, Argonne, IL) to F. Adeshina (EPA, Washington, DC), July 14