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Ten Years of Change: National Library of Medicine TOXMAP Gets a New Look

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Abstract

The United States National Library of Medicine (NLM) TOXNET® databases <<http://toxnet.nlm.nih.gov>> provide broad coverage of environmental health information covering a wide variety of topics, including access to the U.S. Environment Protection Agency (EPA)'s Toxics Release Inventory (TRI) data. The NLM web-based geographic information system (GIS), TOXMAP® <<http://toxmap.nlm.nih.gov/>>, provides interactive maps which show where TRI chemicals are released into the environment and links to TOXNET for information about these chemicals. TOXMAP also displays locations of Superfund sites on the EPA National Priority List, as well as information about the chemical contaminants at these sites. This column focuses on a new version of TOXMAP which brings it up to date with current web GIS technologies and user expectations.

Keywords

Chemical releases; environmental health; GIS; maps; superfund; toxicology; TOXMAP; TRI

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/wmrs.

More information about TOXMAP can be found at: <<http://www.nlm.nih.gov/pubs/factsheets/toxmap.html>>. Questions about TOXMAP can be sent to Dr. Colette Hochstein (colette@nlm.nih.gov) or to tehip@tehl.nlm.nih.gov.

INTRODUCTION

The Division of Specialized Information Services (SIS) <<http://sis.nlm.nih.gov>> is part of the National Library of Medicine (NLM) <<http://nlm.nih.gov>>, at the National Institutes of Health in Bethesda, Maryland. SIS produces TOXNET <<http://toxnet.nlm.nih.gov>>, a group of databases and biomedical information products pertaining to environmental health, chemicals and drugs, diseases and the environment, occupational safety and health, poisoning, risk assessment and regulations, and toxicology.

The Emergency Planning and Community Right to Know Act requires certain U.S. industrial facilities to report annual release amounts of Toxics Release Inventory (TRI) chemicals to the U.S. Environmental Protection Agency (EPA) based on production thresholds (manufactures or processes more than 25,000 pounds of a TRI-listed chemical or otherwise uses more than 10,000 pounds of a listed chemical in a given year), company size (employs 10 or more full-time equivalent employees), industry sector (manufacturing, mining, electric power generation), and other criteria.¹ These reports,

... are intended to provide information to federal, state, and local governments, and to the public, including citizens of communities surrounding covered facilities. The release form shall inform persons about releases of toxic chemicals to the environment; to assist governmental agencies, researchers, and other persons in the conduct of research and data gathering; to aid in the development of appropriate regulations, guidelines, and standards; and for other similar purposes.²

The EPA publishes its TRI data on the web through a variety of reports, query tools, and downloadable files. It makes in-depth information about the TRI program available, such as a yearly TRI national analysis. SIS also provides TRI data (1987 to the most current year available) through its multi-database resource, TOXNET. TOXNET covers specific chemicals, mixtures, and products; chemical nomenclature; identification of unknown chemicals; special toxic effects of chemicals in humans and/or animals; and citations from the scientific literature. It also offers links to NLM PubMed® <<http://www.ncbi.nlm.nih.gov/pubmed/>>, which delivers more than 23 million citations for biomedical literature from MEDLINE, life science journals, and online books.

BACKGROUND

NLM strives to encourage the use of high-quality information.³ It actively explores technologies with the potential to make its information and resources understandable to a diverse audience. Geographic Information Systems (GIS) are one such tool; they integrate hardware, software, and data to capture, manage, analyze, and display geographically referenced information. GIS can help users view, understand, and visualize data and to discover otherwise difficult-to-recognize relationships, patterns, and trends.

NLM released TOXMAP in 2004 (see Figure 1). It was built with ArcIMS, proprietary GIS software from Esri <<http://www.esri.com>>, a GIS industry leader. TOXMAP mapped TRI chemical releases and linked to TOXNET and other authoritative resources for health information about these chemicals. It also included geographic search capability for U.S.

cities, ZIP codes, counties, and other locations and linked to location-based bibliographic references and to other online resources about the TRI chemicals. TOXMAP was developed to be easy to navigate and to understand.

In 2006, EPA Superfund Program sites on the National Priorities List (NPL) were included in TOXMAP. These locations can be found throughout the United States and its territories; they contain substances that are either designated as hazardous under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or are identified as such under other laws. Over the next eight years, TOXMAP added additional map layers (e.g., age, gender, income, cancer, and disease mortality), an advanced search, custom geographic regions, the ability to save search results and view them in Google Maps/Earth, TRI regional releases summary tables, auto-completion of chemical names, more realistic-looking maps, and content for teachers.

TOXMAP REDESIGN

The initial release of TOXMAP preceded most web-based interactive mapping systems, including Google Maps. Users' expectations of such maps were later redefined by Google, Bing, GeoCommons, OpenStreetMap, and other mapping platforms which feature dynamic map behavior and a rich user experience. Esri later began migrating away from ArcIMS toward ArcGIS for Server software and to client development with Adobe Flex and other technologies. Subsequently, NLM recognized that an updated, "next-generation" TOXMAP leveraging these advances was needed.

A new TOXMAP called for a complete redesign; everything needed to be reevaluated. The resource's GIS and virtually all of its other components had significantly evolved since it was first released. Databases, web servers, and client frameworks that run in the user's web browser had to be reviewed in light of the growth of the past decade. The underlying GIS required an upgrade to the more modern Esri ArcGIS for Server to replace the now unsupported ArcIMS.

NLM staff brainstormed which existing features to carry over from the original TOXMAP and which new ones were now possible. Locations of U.S. commercial nuclear power plants were incorporated and other data sets were considered for inclusion because the new software and GIS architecture permitted much easier integration.

Two proofs-of-concept were developed, one with JavaScript, the other with the Esri Web ADF, a client technology that ultimately fell out of favor in the Esri community. The decision was made to embrace the user experience benefits of a "rich Internet application" (RIA) based on Adobe Flash/Flex and to leverage the ArcGIS Viewer for Flex, a customizable sample application created by Esri using Flex.

An interactive prototype was built with the Flex framework, replacing more traditional browser technologies like HTML, Java, JSP, and JavaScript. The MySQL database used by the older TOXMAP was replaced by the latest version of the PostgreSQL database. Data import procedures were devised for the new GIS and its geodatabase. The system was

installed on new production hardware with more processing power, memory, and disk space than its predecessor.

Based on previous success with professionally moderated, web-based focus groups early in resource development,⁴ NLM staff followed a similar evaluation model for the redesigned TOXMAP. When a usable prototype of a Flash-based TOXMAP was ready, trained experts moderated usability sessions that included both technical and non-technical participants. In combination, they performed a heuristic review of the prototype and prepared a detailed report of their own comments coupled with a qualitative analysis of data derived from usability testing. In addition, several informal focus groups were conducted with available NLM staff and interns. Significant changes to the TOXMAP interface resulted from these different forms of feedback.

During this period, other aspects of the transition to a rebuilt TOXMAP were planned. A new website was designed to help users determine which of the two resources best fit their needs. The FAQ and Glossary were adapted and enhanced. Two video tutorials were created: a general “TOXMAP Tour” demonstrating key features, and “Searching TOXMAP by Chemical,” which concentrates on TRI and Superfund search and search results.

The new version of TOXMAP was released December 2013. The new home page was released May 2014.

ISSUES AND CHALLENGES

TOXMAP staff encountered a variety of practical, technological, and budgetary challenges. Due to a federal government budget decrease during this phase, funding for the project was reduced from two developers to less than one. Since the previous version of TOXMAP was still operational and required substantial maintenance, that developer could spend only a portion of his time working on the new resource. Maintenance tasks included adding annual TRI updates, addressing security issues identified by NLM’s robust protocols, and implementing bug-fixes and minor enhancements.

Demands also stemmed from conference presentation obligations, from non-TOXMAP GIS prototype designs, and from the need to support other projects. Because every component of the old TOXMAP had to be replaced for the new version, investigation, understanding, implementation, and testing of many new technologies were required. The Adobe Flash/Flex framework and its underlying programming language ActionScript were completely new to the team and entailed a significant learning curve. In addition, the ArcGIS Viewer for Flex application framework upon which TOXMAP was built was evolving rapidly. Working with such a “moving target” necessitated rewriting code and rethinking assumptions as updated versions were published.

Early prototypes of the new TOXMAP revealed that searching a complex data set such as TRI and presenting results in an intuitive, interactive manner would require an atypical workflow because the chosen back-end GIS software was not designed for database-level searching of millions of records. TOXMAP staff was obliged to develop an alternative

approach involving a PostgreSQL database and an additional web-based communication mechanism which TOXMAP still uses today.

Finally, it became clear during usability testing that some challenges TOXMAP posed for users were related to unfamiliarity with Flex-based user interfaces rather than to the resource itself. Despite many changes made to the default Flex look-and-feel based on usability and other feedback, some TOXMAP users will need to become accustomed to the visual cues, interactive elements, and graphical style of an Adobe Flex application.

THE NEW TOXMAP

The new version of TOXMAP—currently in beta—provides an improved map appearance and interactive capabilities, as well as a more current GIS look and feel. This includes seamless panning, immediate updating of search results when zooming to a location, two collapsible side panels to maximize map size, and automatic map adjustment after a window resize. The new TOXMAP also contains enhanced U.S. Census layers available by Census Tract (2000 and 2010), Canadian National Pollutant Release Inventory (NPRI) data, U.S. commercial nuclear power plant locations, and updated congressional district boundaries. More features are planned, including some present in the older version of TOXMAP which are not currently provided in the new one—most notably, cancer and disease mortality layers and the ability to save search results.

TOXMAP opens with a Welcome Window (see Figure 2) that offers background information about the resource and that lets the user choose among its major features, which are also available on the TOXMAP toolbar. “Browse” allows users to explore the data, turn map layers on and off, and click on facilities/sites to get more detail (see Figure 3). “Zoom to Location” moves the map to a specified address, city, state, ZIP code, place, or latitude/longitude coordinate location. “Search” displays TRI and/or Superfund facilities based on user criteria such as chemical, location, and TRI year (see Figure 4). “US Census and Health data” overlays demographic and economic layers that are color-coded at the county and census tract level (see Figure 5). “Bookmarks” lets users name and save their map area (but not the data on the map) so that they can easily zoom back to the marked location. “Chemical Information” links to resources from the NLM, EPA, Centers for Disease Control and Prevention (CDC), and other government entities. Side panels can be collapsed to allow a larger view of the map or search results. In addition, windows can be minimized and positioned anywhere on the screen. “Help” offers a variety of content to assist users, including links to the FAQ, Glossary, and tutorials.

NLM determined that the previous TOXMAP (renamed “TOXMAP classic”) would remain operational with updated data but no new features. A new TOXMAP home page (see Figure 6) helps users choose between versions and contains a Glossary, FAQ, and News.

CONCLUSION

For more than ten years, TOXMAP has provided a way to explore toxic chemical releases and locations, via interactive maps and links to a variety of toxicology and environmental health resources. Its intuitive maps and user interface have helped to make environmental

health data understandable to a wide range of users. GIS technologies have matured at a rapid pace over this period, creating a compelling need to keep TOXMAP's underlying architecture continually updated. Professional usability sessions and heuristic reviews have and will continue to inform TOXMAP interface and design choices as the resource evolves to keep up with both technology and with user expectations.

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FIGURE 1.
TOXMAP facilities map, 2004.

FIGURE 2.
Welcome window for the new version of TOXMAP.

FIGURE 3.
Browse TOXMAP Data and get facility details.

FIGURE 4.
 Search TRI releases and Superfund NPL sites.

FIGURE 5.
County- and census tract-level demographic layers.

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TOXMAP Environmental Health Maps

Home | About | News | FAQ | Glossary

NLM Environmental Health Portal

Two Ways to Explore Toxic Chemicals in Your Community

TOXMAP classic

TOXMAP classic provides an Advanced Search as well as the ability to save search results and to build custom regions to focus your search. It does not require Flash and is accessible to users with disabilities. No new features are planned.

TOXMAP beta

The beta version of TOXMAP is in active development. It has an improved map appearance and interactive capabilities as well as improved U.S. Census layers, availability by Census tract, and additional and updated datasets.

Note: Both versions of TOXMAP open in new windows - please disable pop-up blockers.

TOXMAP belongs to a group of TOXNET databases related to toxicology, hazardous chemicals, environmental health, and toxic releases.

News

- TOXMAP beta now includes TRI 2012 data
- New TOXMAP web site
- See all TOXMAP news

More Information

- What is TOXMAP?
- Which TOXMAP should I use?
- What is the Toxics Release Inventory (TRI)?
- What is the "Superfund" Program?
- Does TOXMAP show all sources of toxic chemicals?
- What data sources does TOXMAP use?
- Learn to use TOXMAP

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Homepage Updated: February, 2014
EPA data: TRI- November, 2012; Superfund- December, 2009

FIGURE 6.
New TOXMAP home page, 2014.