ELSEVIER

Toxicology 173 (2002) 153–166

TOXICOLOGY

www.elsevier.com/locate/toxicol

WEB resources for pesticide toxicology, environmental chemistry, and policy: a utilitarian perspective

Allan S. Felsot *

Washington State University, 2710 University Drive, Richland, WA 99352, USA

Abstract

Information about pesticides has grown exponentially over the last four decades and is marked by a diversity of sources including government, universities, environmental advocates, and industry. The internet has made access to this unprecedented amount of information faster than ever, but judging the validity and usefulness of the information is problematic. To avoid turning this discussion of web resources for pesticide information into a narrative about a personal 'top ten' list, a utilitarian perspective of resources useful to a research, educator, and risk communicator is elucidated. Useful web sites are fit into the context of information needed for risk assessment, which includes hazard identification, dose-response relationships, exposure assessment, and risk characterization. In addition resources for pesticide policy and regulations are considered. Specific ways in which the sites are useful are discussed along with information about site updating and validation of information.

Keywords: Pesticides; Internet; Databases; Toxicology; Environmental chemistry; Risk assessment; Risk communication

1. Introduction

Pesticides are probably the most intensely regulated and scrutinized chemical technology, so naturally information about them has increased exponentially over the last four decades. Prior to the widespread use of the Internet, information was not available to the public at large, but practicing scientists could rely on scientific journals. Government reports were difficult to access, especially on short notice. Databases about pesticide chemical and biological properties were almost nonexistent. With several exceptions, industry scientists were not encouraged to publish yet, they generated the information that the Environmental Protection Agency (EPA) almost exclusively used to regulate pesticides.

The limited access to detailed pesticide information has become history as the Internet has created an unprecedented window on contaminant information. The principals generating, needing, and disseminating pesticide information have proliferated from research scientists and government agencies to environmental advocacy groups, farmers, and consumers.

Several consequences arise from the speed with which we can obtain information through the Internet and the seemingly limitless subject sites to explore. First, the magnitude of information

* Tel.: + 509-372-7365.
E-mail address: afelsot@tricity.wsu.edu (A.S. Felsot).

PII: S0300-483X(02)00029-X

available from all sources has grown so rapidly that handling and assimilating it with the objective of easily retrieving it requires vigilance and organization. The second dilemma is how to judge information validity. Good, equivocal, and poor information can be exchanged so freely and quickly as to give all the shine of validity. Thus, I would argue that all information, whether from government or non-government organizations (NGOs), should be viewed through a skeptic's gaze.

In exploring further the question of information validity, I have noted that the problem is much more than just 'wrong facts'. The purpose of the information, or alternatively, what the information is needed for, might not be compatible with the type of information presented at any particular web site. For example, one can obtain a wealth of information about toxicological hazards of a pesticide at any number of NGO sites. If hazards are all that you are interested in, those sites will meet your needs. However, if you want to answer the question of the likelihood (i.e. risk) of an adverse reaction given a unique set of conditions (i.e. exposure), then hazard oriented sites will not be nearly as useful as sites providing information about sensitive toxicological endpoints, dose-response relationships, and environmental chemistry (i.e. residue behavior and exposure potential).

A paper on digital sources for specific toxicological subject areas can easily devolve into a laundry list of an author's favorite sites. Such an approach would just contribute to your information overload, not to mention appearing to be a chaotic rendition of a 'top 10' list. In an effort to be informative about the types of digital resources for pesticide information without resorting solely to a narrative travelogue of what you will see when you get there, I decided to approach the subject from the viewpoint of a person needing information for a specific purpose—risk communication, teaching, and/or research. Thus, my approach is practical, not necessarily exhaustive. Nevertheless, popularly used sites mentioned in other endeavors to review digital toxicology resources (for example, Brinkhuis, 2001; Montague and Pellerano, 2001; Poore et al., 2001; Keita-Ouane et al., 2001; Wexler, 2001; Wright, 2001; Wukovitz 2001) were also commonly useful for accessing pesticides information.

2. Approach

I decided to imbue this review with a somewhat personal perspective as an environmental toxicologist with an assignment in the Cooperative Extension Service (CES), which is commonly located in each state's land grant university within traditionally named Colleges of Agriculture. Besides the typical faculty duties of research and teaching, I am also responsible for risk communication. My clients, as we are fond of describing constituencies in the CES, include other faculty and county extension agents, public school students, farmers, business managers, government regulators, and consumers. As expected, many of the questions are toxicological in nature.

As a researcher and teacher, I access and read a wide diversity of journals in broad areas of toxicology and environmental chemistry. The evolution of university libraries as digital gateways for journals has definitely helped those traditional roles. No doubt, my background knowledge about pesticide toxicology obtained from traditional scientific information sources is helpful in communicating with my audience. But the advent of website databases and non-journal reports has allowed me to rapidly answer constituents' questions, sometimes in real time while on the phone as my fingers scurry about the keyboard calling up useful websites. Ironically, the rapid publication on the web of many reports by advocacy groups also generates further inquiries to my office. My experiences as a pesticide specialist, therefore, led me to approach this digital information review from the viewpoint of the diversity of requested information.

Basically, I offer information about agrochemical hazards, risks, and policies. Thus, I examined my favorite web sites for what information they provide in these broad areas.

From the perspective of information needs in pesticide risk assessment, I look for information concerning hazard identification, sensitive toxicological endpoints and dose-response characterization, exposure characterization, and risk characterization. The latter aspect, risk characterization, may not be useful or necessary for many types of information requests, but it does form a useful benchmark for comparison to a specific situation regarding pesticide-related accidents or residue exposure questions.

For pesticide policy assessments, I look for information about specific science policies, most often generated by the EPA as the nation's pesticide manager under the statutory authority of FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act) and FFDCA (Federal Food Drug and Cosmetic Act). I also look for commentaries regarding the scientific validity of these policies, as well as the perceived efficacy of these policies in obtaining desired goals of environmental and human health protection. In this respect, I regularly visit NGO sites because they routinely challenge the adequacy of EPA policies.

To determine the utility of web sites regarding my information needs, I first divided the digital universe by the kind of organization managing the site. The categories were government (state and federal), university (extension and academic departments), and non-governmental organization (includes advocacy groups and industry). Given my needs for specific aspects of risk assessment information, I reviewed the various categories of sites for their adequacy in providing that information. Where possible, I mention the frequency of updating and the likelihood the information is validated. Finally, I mention the usefulness of the site to other parties, including technical specialists, educators, policy makers, or the consumer. The major web sites that I reviewed and my opinion of their utility are summarized in Table 1.

3. Information for pesticide risk assessment

3.1. Hazard identification and toxicological endpoints

3.1.1. The Environmental Protection Agency

Narrative descriptions of pesticide hazards are the most common type of information available on the Internet. The particular digital resource I first use in answering inquiries about pesticide hazards depends on the pesticide. The first stop is usually the EPA Office of Pesticide Programs (OPP) web site (http://www.epa.gov/pesticides). Specifically, I search the Pesticide Reregistration Status site (http://www.epa.gov/pesticides/reregistration/status.htm) to determine if EPA has issued a Reregistration Eligibility Decision (RED) document for the compound. Amendments to FIFRA since the 1980s have reiterated the requirement for EPA to reregister pesticides periodically and update their risk assessment in light of new data since the initial registration. After reviewing all the old and new data, EPA issues a decision as to whether the compound should be reregistered and any new restrictions on use.

The RED site contains an alphabetical listing of all pesticides for which a formal RED has been issued. Finding whether a specific active ingredient has a RED is facilitated by an alphabetical index link at the top of the page. Only compounds with REDs and/or fact sheets are listed. Each entry has the EPA-assigned case number, the status of the RED (e.g. when it was issued) and a downloadable portable document format (PDF) file of the full RED. A background in toxicology is very helpful in deciphering the REDs, but the writing style is accessible and jargon is usually well defined. A shorter less technical fact sheet is also included for each pesticide.

The RED itself contains summaries of required data that a pesticide manufacturer submits to EPA in accordance with testing guidelines. The RED is typically divided into a human health and ecological risk assessment. The RED will start with a section on pesticide physical properties, registered uses, and old and proposed changes in residue tolerances.

The pesticide hazards are identified in a section that describes the battery of animal tests used to make a registration decision. Toxicological responses are usually tied to specific doses. Most importantly, the RED discusses EPA's rational for choosing toxicological endpoints of concern and associated No Observable Adverse Effect Levels (NOAELs) and Lowest Observable Adverse Effect Levels (LOAELs).

Table 1
Pesticide web resources and utility of information provided

Web resource	Type of organization	Pesticide risk assessment information				Science policy and regulations
		Hazard identification	Dose–response characterization	Exposure assessment	Risk characterization	
Breast cancer environmental risk factors (http://www.cfe.cornell.edu/bcerf/)	University	X	X	X		
California department of pesticide regulation (http://www.cdpr.ca.gov/)	Government	X	X	X		X
Consumers union-FQPA (http://www.ecologic-ipm.com/menu.html	NGO				X	X
Crop Data Management Services, Inc. (MSDS) (http://www.cdms.net/manuf/manuf.asp)	NGO	X	X			
Environmental working group (http://www.ewg.org)	NGO			X	X	X
EPA biopesticides (http://www.epa.gov/pesticides/biopesticides/)	Government	X	X	X	X	
EPA ecological risk assessment (http://www.epa.gov/oppefed1/ecorisk/)	Government					X
EPA ECOTOX (http://www.epa.gov/med/databases/databases.html)	Government	X	X			
EPA fact sheets for new registrations (http://www.epa.gov/opprd001/factsheets/)	Government	X	X			
EPA food quality protection act (http://www.epa.gov/oppfead1/fqpa/backgrnd.htm)	Government					X
EPA integrated risk information system (http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?IRIS)	Government	X	X			
EPA laws & regulations (http://www.epa.gov/epahome/rules.html)	Government					X
EPA center for exposure assessment modeling (http://www.epa.gov/ceampubl/products.htm).	Government			X		
EPA office of pesticide programs (http://www.epa.gov/pesticides)	Government	X	X	X	X	
EPA OP insecticide tolerance reassessment (http://www.epa.gov/pesticide/op)	Government	X	X	X	X	
EPA pesticide re-registration status (http://www.epa.gov/pesticides/reregistration/status.htm)	Government	X	X	X	X	X

Table 1 (*continued*)

Web resource	Type of organization	Pesticide risk assessment information				Science policy and regulations
		Hazard identification	Dose–response characterization	Exposure assessment	Risk characterization	
EPA scientific advisory panel (http://www.epa.gov/scipoly/sap/)	Government				X	X
EPA tolerance reassessment advisory committee (http://www.epa.gov/pesticides/trac/science/)	Government					X
EPA water quality criteria and standards (http://www.epa.gov/ost/standards/wqcriteria.html)	Government		X			X
EXTOXNET (http://ace.orst.edu/info/extoxnet/)	University	X	X	X		X
FDA-center for food safety & applied nutrition (http://vm.cfsan.fda.gov/~lrd/pestadd.html)	Government			X		
Federal register (http://www.epa.gov/fedrgstr/search.htm)	Government	X	X	X	X	X
Meister pro crop protection knowledge central (http://www.meisterpro.com/members/members–PesticideDictionary.asp)	NGO	X	X			
National pesticide information center (http://npic.orst.edu)	University	X	X			
New jersey department of health and senior services hazardous substance fact sheets (http://www.state.nj.us/health/eoh/rtkweb/rtkhsfs.htm # D)	Government	X				
Northwest coalition for alternatives to pesticides (http://www.pesticide.org/)	NGO	X				
Pesticide action network of north America (http://www.panna.org/)	NGO	X				
Pesticide.net (http://www.pestlaw.net/)	NGO					X
Spray drift task force (http://www.agdrift.com/)	NGO			X		
TOXNET (http://toxnet.nlm.nih.gov/)	Government	X	X	X		
US geological survey-national water quality assessment program (NAWQA) (http://water.usgs.gov/nawqa/nawqa_home.html)	Government			X		
US geological survey NAWQA pesticide national synthesis project (http://water.wr.usgs.gov/pnsp/)	Government			X	X	
US forest service pesticide management (http://www.fs.fed.us/foresthealth/pesticide/)	Government	X	X	X	X	

Table 1 (*continued*)

Web resource	Type of organization	Pesticide risk assessment information				Science policy and regulations
		Hazard identification	Dose–response characterization	Exposure assessment	Risk characterization	
USDA national agricultural statistics service (http://usda.mannlib.cornell.edu/reports/nassr/other/pcu-bb/)	Government			X		
USDA pesticide data program (http://www.ams.usda.gov/science/pdp/what.htm)	Government			X		
USDA pesticide properties database (USDA PPD) (http://wizard.arsusda.gov/acsl/ppdb.html)	Government			X		

Once EPA identifies the NOAEL, it typically applies a 100-fold uncertainty (i.e. safety) factor to set the reference dose (RfD). EPA interprets the RfD as the acute or chronic dose not to be exceeded to ensure a reasonable certainty of no harm. Under the Food Quality Protection Act (FQPA) of 1996, (http://www.epa.gov/oppfead1/fqpa/backgrnd.htm) the EPA must apply up to another ten-fold safety factor to the RfD, creating a new endpoint, the population adjusted dose (PAD). The PAD represents a dose reasonably sure to be protective of children. The RED will explain the rationale EPA uses for setting a PAD if an extra safety factor is necessary. The use of uncertainty factors for defining RfDs and PADs is really based on science policy rather than tested toxicological principles, but they form the basis for eventually doing the risk characterizations.

One drawback to the RED site is that it does not contain every registered active ingredient. Many of the compounds with REDs had already been registered for many years. Thus, another strategy I use to gather information about compounds without REDs is to use the Federal Register (FR) search site (http://www.epa.gov/fedrgstr/search.htm). The Federal Register serves as the US government's official notification of all rules and regulations proposed and finalized by the agencies of the executive branch. On the search page, a pesticide active ingredient can be searched across all electronically archived FR issues or just 1 days issue. The typical document retrieved will be a notification of an EPA action regarding a pesticide tolerance. EPA will review the mammalian toxicology behind its decision to issue or change a pesticide tolerance. The tolerance notification includes a description of the various toxicological studies and their resulting NOAELs. The FR notification gives outside parties an opportunity to respond to the tolerance petition. Pesticide tolerance notifications do not include information about the ecological risk assessment conducted prior to pesticide registration.

Following the passage of the FQPA, the EPA decided to review first the acetylcholinesterase-inhibiting organophosphorus insecticides (OP). Thus, if a question arises concerning the 40 active ingredients in this class, I can query the OP tolerance reassessment site directly (http://www.epa.gov/pesticide/op). The OP assessments are also accessible through the REDs web site.

Pesticide technology is changing rapidly, and as the cholinesterase inhibitors are phased out, pesticides of much lower hazard but higher specificity are replacing them. EPA has issued fact sheets on new pesticide registrations (http://www.epa.gov/opprd001/factsheets/). The site lists the date of registration, EPA code, type of pesticide and whether it is reduced risk, and date of issue. The fact sheets are in PDF format.

Natural products, pheromones, and microbial pesticides are collectively referred to as biopesticides. EPA OPP has organized a plethora of hazard information about biopesticides into one web site (http://www.epa.gov/pesticides/biopesticides/). The site includes fact sheets, decision documents, product lists, labels, company lists, study reviews, and bibliographies.

The biopesticides web site also has information about plant incorporated protectants, EPA's euphemism for genetically modified organisms (GMOs) containing a genetic trait producing a pesticidal compound. Questions about the human and environmental safety of transgenic crops have increased recently, so the biopesticides web site has become a good place to start a search on the most current information. For example, information is available on crops engineered to express the Bt (*Bacillus thuringiensis*) insecticidal crystalline protein. From the biopesticides site, I can link to the FIFRA Scientific Advisory Panel (SAP) web site (http://www.epa.gov/scipoly/sap/) to gain access to the assessments of Bt crops. From the SAP site I can link to the recent Centers for Disease Control (CDC) information (http://www.cdc.gov/nceh) on putative allergenic hazards of the Starlink cultivar of Bt corn, which made worldwide headlines because it was registered only for consumption by livestock but was inadvertently introduced into the human food chain.

If I need quick information on pesticide toxicity to nontarget organisms, like birds and fish, I can access EPA's on-line collection of databases known as Ecotox (http://www.epa.gov/med/databases/databases.html). As described on the web page, Ecotox ''is a comprehensive computer-based system that provides chemical-specific toxicity values for aquatic life, terrestrial plants, and terrestrial wildlife.'' The database actually consists of several parts: ACQUIRE for aquatic organisms, PHYTOTOX for plants, and TERRETOX for wildlife. The databases are searchable by compound. The retrieval report lists the LD50 generated from short term testing, and the NOAEC or LOAEC for chronic studies. The source of information is also given.

3.1.2. TOXNET

TOXNET (http://toxnet.nlm.nih.gov/) is a collection of informational and literature databases developed by the National Library of Medicine (see detailed review by Wexler 2001). Many of the currently registered and suspended pesticides are listed in the Hazardous Substances Data Bank (HSDB). Compounds registered within the last 5 years are not likely to be found here. In addition to pesticides, some of the inert ingredients in pesticide formulations are also cataloged on HSDB. Unfortunately, I often have to obtain the identity of inert ingredients through non-electronic sources as there are currently a lot of public questions about these materials but little information available on the Web.

The HSDB has been particularly useful to me for answering questions about likely human health symptoms from pesticide exposure. In addition to a human health effects section, the HSDB annotates results from animal testing and environmental fate. Particularly helpful are citations of the source material (often from the published journal literature) following each annotation.

Many questions I receive from the public involve acute exposures. However, I am commonly asked about chronic effects, especially cancer. Thus, TOXNET is very convenient because I can easily link from the home page to EPA's IRIS (Integrated Risk Information System) site (http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?IRIS) to determine the status of carcinogenicity testing for the majority of pesticides likely to be used by consumers. IRIS also has detailed information about noncarcinogenic hazards and dose-response relationships. The links to CCRIS (Chemical Carcinogenesis Research Information System) and GENE-TOX databases are also useful for obtaining information about carcinogenic hazards.

A very convenient feature of TOXNET is its direct link to TOXLINE (http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?TOXLINE), a database of published literature. When a specific pesticide that I need information for is not listed in HSDB, the TOXNET site allows me the option of searching for the compound in TOXLINE. For example, I was preparing a risk communication for imidacloprid, a comparatively new neonicotinoid insecticide, but no RED had been published on-line nor did HSDB have a listing. Through, TOXLINE, however, I was able to conveniently search the published literature and access citations and abstracts that helped with understanding imidacloprid's biochemical toxicity and the reasons for its extraordinary differential toxicity between insects and vertebrates, despite the commonality of binding to the nicotinic acetylcholine receptor. I combined the information obtained through TOXLINE with a pesticide tolerance notification obtained through a Federal Register search to complete the hazard assessment portion of the document I was preparing.

3.1.3. University

Touting itself as containing objective, 'science-based information about pesticides-written for the non-expert', the EXTOXNET site (http://ace.orst.edu/info/extoxnet/) has summarized information for most of the currently registered active ingredients. The site was created with Federal funding as a cooperative venture among Oregon State University, Michigan State University, Cornell University, the University of California-Davis, and the University of Idaho. The site is hosted and maintained by Oregon State University.

The EXTOXNET database is divided into separate links to toxicology and environmental chemistry information for individual pesticides (called Pesticide Information Profiles, PIPs), essays explaining various toxicological principles and concepts (Toxicology Information in Brief, TIBs), and explanations of some of the controversial issues receiving media attention (Toxicological Issues of Concern, TICs). Each of the links contains a search line for quick access to specific pesticide active ingredients or key terms. The PIPs page also has an alphabetical listing of all the cataloged active ingredients.

While I do not often choose EXTOXNET's PIPS site first when looking for specific information about pesticides, I do compare the information from other sites with the information on EXTOXNET to be sure there is consistency in interpretation among different organizations. The references used to develop the PIPs summaries are listed in linked files. Some citations refer to published journal literature, but most are secondary sources that would provide the primary references for interested users. Most but not all of the PIPs are dated. For older dated pesticides, information sometimes seems incomplete, probably because it is not clear if the published literature is routinely reviewed to fill in missing data absent from the referenced source material. Nevertheless, the summaries include information ranging from toxicology to ecological fate and effects, and are written in a manner easily accessible to the public.

The National Pesticide Information Center (NPIC) is best known as a toll-free telephone based inquiry service (1-800-858-7378) for science-based information about pesticide products, recognition and management of pesticide poisoning, toxicology, and environmental chemistry. The service is operated by Oregon State University under contract to the EPA. The service currently includes the National Antimicrobial Information Network (NAIN) that provides information about antimicrobial products generally regulated under FIFRA, including sanitizers, disinfectants, and sterilants. However, after March 31, 2002, NAIN will be closed and antimicrobial product queries referred to the Antimicrobials Division of EPA OPP.

The web sites for NPIC (http://npic.orst.edu) and NAIN (http://nain.orst.edu/index1.htm) are searchable by product and provide general technical information. Fact sheets downloadable as PDF files have been developed for some active ingredients (19 at this time) and are written in non-technical language. Some of them give detailed information about both hazards and dose-response relationships (for example, see the fact sheet for the insecticide synergist piperonyl butoxide). Fact sheets have also been developed on specific pesticide topics. One notable fact sheet has tackled the mysterious subject of inert ingredients, but owing to the general secrecy of identity of these constituents in product formulation, little specific information is given. The fact sheets contain references, and where web-based information is cited, the dates of latest access are included.

From a research perspective, I find the BCERF (Program on Breast Cancer and Environmental Risk Factors in New York State) web site (http://www.cfe.cornell.edu/bcerf/) the best for detailed analysis of past and recent scientific literature on specific pesticides. The mission of BCERF is to address "the relationship between environmental risk factors and breast cancer through a variety of research and education strategies." Developed by Cornell University under grants from New York State and the US. Department of Agriculture, the site has downloadable PDF files of critical analyses and HTML formats of fact sheets and bibliographies. The HTML fact sheets seem designed for public risk communication, whereas the critical analyses seem oriented to researchers and technical experts. In fact, the critical analyses are more like journal article reviews and would be excellent for undergraduate or graduate toxicology classes. While the overriding concerns are relationships between exogenous as well as endogenous risk factors for breast cancer, the reviews contain excellent analyses of all pesticide hazards known from animal studies as well as dose-response relationships. The reviews are especially good for overviews of human epidemiological studies in relation to cancer in general. The site's Environmental Risk Factor (ERF) Database contains over 5000 bibliographic records and is searchable by author, title, journal, or keyword. All the HTML documents contain update information and the names of authors who prepared the material.

3.1.4. NGOs: environmental advocacy groups

Environmental advocacy groups (EAGs) that are focused on chemical toxicity issues have proliferated over the last 20 years, and all have very attractive web sites that will pop up in casual searches for pesticides in general, and for the more popularly used pesticides in particular. Two sites are particularly worthy of mention for the information they contain on hazard identification—NCAP (Northwest Coalition for Alternatives to Pesticides, http://www.pesticide.org/) and PANNA (Pesticide Action Network of North America, http://www.panna.org/).

Of course, subtitles on web sites such as "Because Our World Is Too Precious to Poison" should invoke the maxim of caveat emptor. Nevertheless, among the various EAGs, I find NCAP to have the best and the most comprehensive bibliographic information on hazard identification. NCAP produces a quarterly publication called Journal of Pesticide Reform. In each issue there is a pesticide fact sheet that is obtainable from their web site as a PDF file. Thirty-one active ingredients are covered in one or more fact sheets. The fact sheets include both human health and ecological hazards. Although, the author of the fact sheets does cite quite a bit of government and published journal literature, the analyses contain strictly hazard information without consideration of dose–response relationships nor exposure. Nevertheless, just as an intellectual exercise, I find the fact sheets challenging from the perspective of ferreting out on my own how the hazards presented actually relate to real world exposures. As a result, the fact sheets are excellent exercises for a toxicology class to take the hazard identification to the next several steps of risk assessment. Furthermore, the nature of some inquiries to my office indicates that the information in NCAPs fact sheets has been read but not put into the context of what the likely exposure is relative to the dose–response relationships.

PANNA has pieced together a searchable database on individual pesticides (http://www.pesticideinfo.org/). The database is in tabular form giving information on acute toxicity (LD50) and whether the compound is listed as a carcinogen or reproductive toxicant in at least one of several federal or state government databases. No information is given regarding dose–response relationships for various hazards. PANNA also publishes a downloadable PDF file of a newsletter called Pesticide Research Updates. The newsletter contains summaries of research published in the refereed literature. Most of the summaries focus on hazard characterization without much attention to dose-response relationships.

Both NCAP and PANNA have been active in lobbying EPA to make pesticide manufacturers disclose the identity and concentrations of inert ingredients in pesticide formulations. Owing to filings of Freedom of Information requests with the agency, the identity of inert ingredients in several commonly used herbicide formulations have been released and are available from each EAG's web site.

3.1.5. NGOs: industry

As expected, industry web sites often provide general information about their product's active ingredients but lack enough detail to be useful for meaningful risk assessments. With respect to hazard characterization, however, the information contributed to the material safety data sheets (MSDS) is useful for consumers and workers who are handling concentrated formulations. Crop Data Management Services, Inc. (http://www.cdms.net/manuf/manuf.asp) has downloadable PDF files of the MSDS and labels for most of the currently registered products. Unfortunately, the site is searchable only by product name, not by active ingredient. The site may also be searched through an index of product manufacturers.

Complementing the CDMS site, the Meister Pro Crop Protection Knowledge Central web site (http://www.meisterpro.com/members/members_PesticideDictionary.asp) will allow searching on active ingredients as well as product formulations. Although the site does not have MSDS's, it is a first place to start if you do not know the specific formulations of an active ingredient. The site is essentially a version of the widely used (among crop protection specialists) Farm Chemicals Handbook.

The only other industry site that I have found useful is the highly specialized Industry Task Force II on 2,4-D Research (http://www.24d.org/).

Although limited in use, I do receive many inquiries on home herbicide use, and 2,4-D is probably the most widely used lawn herbicide. The site indicates when it is updated. Its bibliographic list does contain annotations. As with the EAGs sites, one has to be cautious about listings that would tend to support a particular viewpoint, but nevertheless the information is extracted from articles in peer-reviewed journals.

3.1.6. Miscellaneous

State regulatory agencies, especially those in charge of registering pesticides, are also useful sources of pesticide information. Although these sites tend to be more useful for specific state regulations, a few have useful hazards information. The California Department of Pesticide Regulation (CDPR, http://www.cdpr.ca.gov/) has a searchable database where information on specific active ingredients can be obtained. The site also has links to other resources. The CDPR site contains downloadable PDF files with concise, referenced information about environmental fate of individual pesticides. In addition to environmental chemistry information (e.g. physicochemical properties, kinetic data for different media), the documents include invertebrate and mammalian toxicity values and a discussion of mode of action.

The 'Right to Know' program supervised by the New Jersey Department of Health and Senior Services offers a searchable databank of hazardous substance fact sheets that includes numerous pesticides (http://www.state.nj.us/health/eoh/rtkweb/rtkhsfs.htm # D). The fact sheets contain much of the same information found in an MSDS but they seem designed for the lay public. Thus, the fact sheets give a broad overview of a substance's hazards, worker protection information, and advice if one is exposed. Each fact sheet contains a glossary and general questions and answers likely to be asked by the public about any potentially hazardous substance.

Many universities have either pest management web sites and/or pesticide applicator training sites which will have a wide diversity of pesticide information. However, those sites tend to focus on pesticides that are legal to use within a state and worker safety than on hazard characterization. Nevertheless the sites tend to have links to other sites with useful hazard identification information.

3.2. Exposure assessment

Other than the EPA web sites for REDs, exposure information is scattered and difficult to find in one place on the web. Using a combination of the EPA REDs and Federal Register web sites, I can piece together information on dietary and drinking water exposure. For the most part, EPA itself relies on food residue databases published by the FDA (http://vm.cfsan.fda.gov/ ~ lrd/pestadd.html) and the USDA (http://www.ams.usda.gov/science/pdp/what.htm). Each agency has made its respective pesticide residues in food databases downloadable as delimited ASCII files that can be imported into EXCEL spreadsheets or other database programs. Users should be aware that the Pesticides and Chemical Contaminants monitoring program of the FDA has a distinctly different mission and regulatory authority than the USDA Pesticide Data Program. Thus, the way that samples are collected and even analyzed are different but still represent the most comprehensive databases of food residues at the post-farm, wholesale distributor level.

For assessment of exposure to drinking water residues, EPA relies strictly on model simulations, employing either a Tier I screening model called SCI-GROW for residues in ground water or a Tier II analysis employing PRZM (Pesticide Root Zone Model). Residues in surface water supplies are estimated using a combination of PRZM and EXAMS (Exposure Analysis Modeling Systems). The EPA has made the models PRZM and EXAMS available through its Center for Exposure Assessment Modeling web site (http://www.epa.gov/ceampubl/products.htm). PRZM predicts surface runoff of pesticide residues, and EXAMS estimates residues in receiving surface waters over time.

In cooperation with EPA, the Spray Drift Task Force, a pesticide industry group, has developed a spray drift assessment model that can estimate downwind deposition of pesticide residues from aerial and ground sprayers. The model can be downloaded (http://www.agdrift.com/) and used to estimate concentrations of pesticide residues in water given certain initial application rates, crop characteristics, and meteorological conditions.

The most comprehensive empirical database of water residue information has been compiled by the US Geological Survey's (USGS) National Water Quality Assessment (NAWQA) Program (http://water.usgs.gov/nawqa/nawqa_home.html). The NAWQA Program is a nationwide watershed/basin based program to study water quality parameters that include pesticide residues and other chemical contaminants. Downloadable PDF files and on-line HTML files for the various basins (also called study units) in the program contain information about detected residues and their concentrations. The data from the regional basins are summarized in a database called the National Synthesis (http://water.usgs.gov/nawqa/nawqa/natsyn/html) with a probabilistic perspective. Residue concentrations are listed in percentiles, making it possible to conduct a risk assessment by considering the 95th percentile of water exposure. The archived raw data (http://water.usgs.gov/nawqa/data) may be downloaded as ASCII files and imported into spreadsheets for personal manipulation and analysis. The National Synthesis summary report also contains EPA and Canadian recommended (and/or regulatory) water quality guidelines for protection of aquatic biota and human health.

EPA's estimates of dietary and drinking water exposure can be modified by considering the percentage of crop acres that are actually treated with a particular pesticide, given the reality that not all crops for which a compound is registered will be treated. These modifications rely on commodity surveys to determine pesticide usage. The USDA National Agricultural Statistics Service surveys field crop (corn, soybean, cotton, wheat) farmers yearly for pesticide use. Fruit and vegetable growers are surveyed biennially. The survey results for the nation as a whole and for individual states are accessible through a web site hosted by Cornell University (http://usda.mannlib.cornell.edu/reports/nassr/other/pcu-bb/). In addition to field crops, fruits, and vegetables, the site also has information on livestock pesticide use and on pest management practices in general.

In addition to empirical monitoring studies of residues in food and water, exposure assessment also relies on environmental chemistry information, especially to make predictions or estimations of environmental residues given certain rates of application. TOXNET has sections on environmental fate that includes summaries of studies measuring half-lives or persistence in soil and water. Physicochemical properties (water solubility, vapor pressure, Henry's Law coefficient, soil sorption coefficients) as well as anticipated soil and water half-lives can be accessed from the USDA Pesticide Properties Database (USDA PPD) (http://wizard.arsusda.gov/acsl/ppdb.html) that lists all the information in a non-annotated tabular form. Like TOXNET, the USDA database also states reference sources for the listed values.

EXTOXNET and NPIC pesticide listings also have general descriptions of half-lives and some physicochemical properties. The Environmental Fate Database with similar information to TOXNET and the USDA PPD is hosted by the private Syracuse Research Corporation (http://esc.syrres.com/efdb.htm) and is free to the public. For information on metabolic pathways likely in soil (as a result of microbial processes), I rely on the University of Minnesota Biocatalysis/Biodegradation database (http://umbbd.ahc.umn.edu/aboutBBD.html). The previously mentioned downloadable environmental fact sheets produced by the CDPR often contain degradation pathways for biota and water in addition to soil.

In addition to a knowledge of residues and how much pesticide is expected to be used, sometimes exposure assessment requires information on all the registered uses, in addition to a cross indexing of active ingredient names with formulation names. For information on the formulations associated with a specific active ingredient and allowed uses, the Washington State University Pesticide Information Center On-line (http://picol.cahe.wsu.edu/~plirs/pl-logscreen.html) keeps a frequently updated electronic database of the over 11 000 state-wide registrations. Many of these formulations and uses will be similar to those registered in other states.

3.3. Risk characterization

Complete risk assessments of individual pesticides are difficult to find on the Internet if EPA has not published a RED. For those compounds having a formal RED, EPA shows the likelihood that exposure will exceed an RfD protective of humans, or an LD/LC50 or NOEC for fish, wildlife, and aquatic invertebrates. The BCERF site specifically assesses whether a pesticide is likely to be a breast cancer risk factor. The IRIS database, accessible through TOXNET, indicates carcinogenicity classifications for many pesticides.

Detailed human health and environmental risk assessments for registered forestry management herbicides are available from the US Forest Service Pesticide Management page (http://www.fs.fed.us/foresthealth/pesticide/). The National Synthesis web pages (http://water.wr.usgs.gov/pnsp/) of the USGS NAWQA Program will show for ground and surface water logarithmically scaled bar graphs of the distribution of pesticide residue concentrations. On each graph, a perpendicular bar indicates where the formal maximum contaminant levels for protection of human health falls as well as the guidance criterion for the protection of aquatic biota. From these graphs one can estimate the likelihood of exceeding various water quality parameters. For information on suggested or promulgated water quality standards, the EPA Water Quality Criteria and Standards web site is one additional place to begin a search (http://www.epa.gov/ost/standards/wqcriteria.html) and will give links to downloadable files.

One environmental advocacy NGO, the Environmental Working Group (http://www.ewg.org), periodically publishes exposé-like reports about various pesticide exposure issues. The reports may include a simplistic risk characterization based on EPA toxicological endpoints of concern. All of the reports are downloadable as PDF files. Pertinently to my responsibilities in risk communication, EWG reports are preceded by a national press release and generate calls from print and radio media, as well as parties in the agricultural industry. I often find the reports ambiguous with regard to the use of peer review for accuracy. Nevertheless I have handed the reports to my classes as an exercise in determining the validity of EWG's conclusions.

4. Science policy

For science policy regarding both regulation of pesticides and how risk assessment are to be carried out, I suggest starting with the EPA web site called 'Science Policy Issues and Documents' (http://www.epa.gov/pesticides/trac/science/). The posting of this collection of risk assessment policies resulted directly from the mandates of the FQPA and administrative requirements for transparency about regulatory decisions. Some of the policies blaze new risk assessment ground (for example, the aggregate and cumulative exposure assessment policies, and the use of Monte Carlo analysis to derive the 99.9th percentile of dietary exposure). Ecological risk assessment policy can be downloaded in PDF format from http://www.epa.gov/oppefed1/ecorisk/. For periodic updates on science policies and commentaries by the EPA Scientific Advisory Panel (SAP) concerning both human health and ecological risk assessment, I visit http://www.epa.gov/scipoly/sap/. The SAP site lists agendas for future meetings, and it includes associated documents prepared by EPA for review.

For commentary challenging EPA's risk assessment policies, especially those stemming from the FQPA, the site hosted by Consumers Union (http://www.ecologic-ipm.com/menu.html) has numerous downloadable PDF files of various reports. The reports seem to be developed in direct response to EPA draft risk assessments of specific pesticides and/or science policy proposals, and they are submitted to the EPA docket during the open commentary periods.

The EPA home page allows access to Federal statutes and regulations (http://www.epa.gov/epahome/rules.html). State pesticide regulations can be accessed through state department of agriculture web sites (for example, http://

www.cdpr.ca.gov/ in California) or through university pesticide information programs sites (a good example is the Clemson university site, http://entweb.clemson.edu/pesticid/index2.htm #). One private resource that has a lot of commentary on pesticide regulations and issues is called Pesticide.Net (http://www.pestlaw.net/), formerly known as Pestlaw. The site is maintained by principals from the law firm of Wright & Sielaty and the scientific and regulatory consultants at ChemReg Int'l. The site is fee-based, but it is free of charge for professionals associated with educational and extension institutions.

5. Conclusions

I have noted that nearly all of the web sites that I have reviewed have multiple links to other sites. I can easily spend hours going through the links, downloading information, and trying to validate claims made in the various reports retrieved from NGO sites. I have observed that the government and university sites generally have referenced information. I tend to view advocacy sites skeptically, the validity of their arguments can be examined by following the trail of references they are commonly listing to reinforce their viewpoint.

In one sense, my job as risk communicator is easier now than a decade ago when I had to rely on the drip method of laboriously building my own literature database and being frustrated by an inability to quickly access government documents. On the other hand, I'm suffering from information overload as the Internet has made easy the ability by any organization to publish information that is used by the public (and media) to form conclusions about pesticide technology. I do not expect any relief soon, but if I had one recommendation to offer purveyors of information on the Internet as well as users, it would be a reminder to take care in differentiating the information about the hazards of pesticides from the likelihood of exposure and adverse effects.

References

Brinkhuis, R.P., 2001. Toxicology information from US government agencies. Toxicology 157, 25–49.

Keita-Ouane, F., Durkee, L., Clevenstine, E., Ruse, M., Csizer, Z., Kearns, P., Halpaap, A., 2001. The IOMC organizations: a source of chemical safety information. Toxicology 157, 111–119.

Montague, P., Pellerano, M.B., 2001. Toxicology and environmental digital resources from and for citizen groups. Toxicology 157, 77–88.

Poore, L.M., King, G., Stefanik, K., 2001. Toxicology information resources at the environmental protection agency. Toxicology 157, 11–23.

Wexler, P., 2001. TOXNET: An evolving web resource for toxicology and environmental health information. Toxicology 157, 3–10.

Wright, L.L., 2001. Searching Fee and non-Fee toxicology information resources: an overview of selected databases. Toxicology 157, 89–110.

Wukovitz, L.D., 2001. Using internet search engines and library catalogs to locate toxicology information. Toxicology 157, 121–139.