Environmental Health Perspectives
Vol 90, pp. 199-208, 1991

A Model Standardized Risk Assessment Protocol for Use with Hazardous Waste Sites

by Gary M. Marsh* and Richard Day*

This paper presents a model standardized risk assessment protocol (SRAP) for use with hazardous waste sites. The proposed SRAP focuses on the degree and patterns of evidence that exist for a significant risk to human populations from exposure to a hazardous waste site. The SRAP was designed with at least four specific goals in mind: to organize the available scientific data on a specific site and to highlight important gaps in this knowledge; to facilitate rational, cost-effective decision making about the best distribution of available manpower and resources; to systematically classify sites roughly according to the level of risk they pose to surrounding human populations; and to promote an improved level of communication among professionals working in the area of waste site management and between decision makers and the local population.

Introduction

Estimating the potential hazards to human populations from waste site exposures has become a central topic of debate and concern among scientists, public health administrators, politicians, trade representatives, environmentalists, community interest groups, and the general public. Given this growing level of concern from so many quarters of our society and the need to develop a viable consensus regarding priorities for future action, it is striking that professionals working in this field have yet to develop a commonly accepted, scientifically defensible approach to the classification of toxic waste sites and their associated health hazards.

This paper puts forward a model standardized risk assessment protocol (SRAP) for use with hazardous waste sites. It must be emphasized from the outset that we do not view the protocol presented here as being in any sense final. Instead, it is meant to serve as a model protocol, that is to say, as a prototype or an example to illustrate an approach to the fundamental problems of classifying the health risks posed by potentially hazardous waste sites and organizing appropriate remedial action in a responsive and efficient manner.

Background

Before presenting the SRAP, it is important to clarify certain basic terminology that will be used in this paper. When one examines the literature on hazardous waste sites, it becomes clear that terms such as "risk assessment" and "risk analysis" are used clear from the context in which they occur. In order to prevent confusion, there are three primary terms that we will define: health risk assessment, standardized risk assessment protocol, and risk analysis.

For the purposes of this paper, a health risk assessment is a generic term covering a broad group of laboratory, environmental, and epidemiological investigations designed to evaluate the health implications of exposures to hazardous waste materials. In contrast, a standardized risk assessment protocol refers to a set of operationally defined criteria that are used as the basis for for site classification and decision making with regard to potential remedial actions. Finally, risk analysis is defined as the calculation of expected numbers of excess cases using exposure and health effects data derived from existing human (e.g., epidemiological) and animal (i.e., laboratory) studies. It will become clear as we proceed that a formal risk analysis is simply one part of a complete health risk assessment and that the model SRAP presented in this paper is an operationally defined set of rules for organizing, classifying, and acting upon the evidence (or lack of evidence) of human health risks derived from health risk assessments.

Figure 1 presents a simple three-phase classification of the activities routinely carried out by public health agencies responsible for dealing with potentially hazardous toxic waste sites. This classification of activities was adapted, in part, from materials published by the Environmental Protection Agency (*1*) and the Agency for Toxic Substances and Disease Registry (ATSDR) (*2*).

In Figure 1, the discovery phase covers the process of the identification of toxic waste sites that pose a potential threat to human populations. The identification of relevant releases may proceed from any one of a broad range of sources, e.g., the National Priority List of Superfund sites, state and local agencies, licensed physicians, lawyers, or community interest groups.

*Department of Biostatistics, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA 15261.

Address reprint requests to G. M. Marsh, Department of Biostatistics, A412 Crabtree Hall, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA 15261.

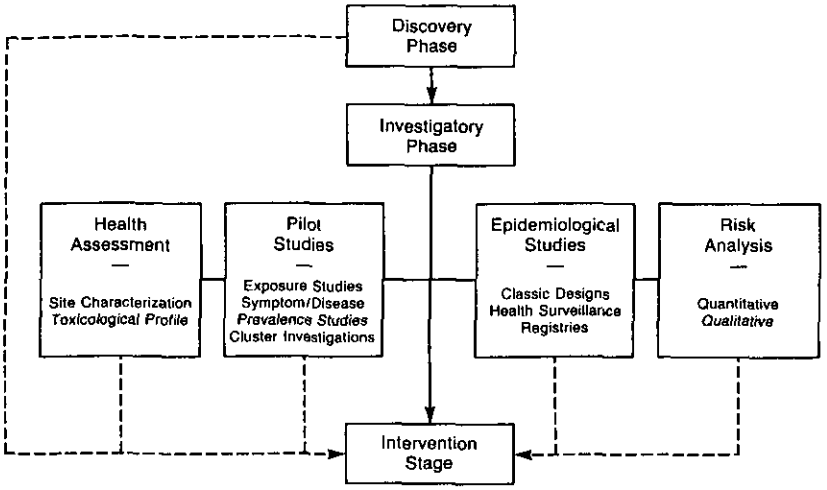

FIGURE 1. Phases of work in the assessment of a toxic waste site (*2*).

Once a site has been identified, an investigatory phase of work may be initiated. This phase of work usually involves a more or less complete health risk assessment and refers to the process of determining whether it is likely that a significant health risk to human populations exists due to a waste site exposure. Under ATSDR guidelines (*2*), for example, the investigatory phase of work encompasses three hierarchical research components: *a*) health assessments, site characterizations and toxicological profiles; *b*) pilot studies, including biological exposure studies, symptom/disease prevalence studies and cluster studies; and *c*) epidemiological studies, including classic research designs, health surveillance studies, and disease registries.

We have added to this a risk analysis component as a fourth possible aspect of the investigatory phase. As noted earlier, this component would draw upon existing animal and human studies to attempt to estimate the number of excess cases of specific health outcomes that may be expected to occur within the population exposed to the site.

Due to restrictions on space, we have simply enumerated and briefly described the components of a complete health risk assessment. Readers interested in obtaining a more complete review of methodological and other difficulties involved in the actual conduct of these investigative activities should refer to previous works (*3,4*).

The intervention phase covers activities undertaken to reduce the demonstrable risk from known releases of toxic substances. Under current federal law [Comprehensive Environmental Response Compensation Act of 1980 (*5*) and Superfund Amendments and Reauthorization Act of 1986 (*6*)], this phase covers a variety of potential ameliorative activities that range from a simple site clean-up to the organization of treatment programs for the members of exposed populations to the power to recommend more extreme steps, such as the provision of alternative community water supplies or the permanent relocation of exposed individuals. Figure 1 shows that, depending upon the characteristics of a site and the immediacy of the evidence regarding a significant risk to human health, it is possible for an administrator to move directly to the implementation of an intervention program from any one of the earlier phases of work.

It is important to note that decision making with regard to the activities outlined in Figure 1 generally takes place in an *ad hoc* manner. That is to say, public health administrators usually have to make decisions without the support of explicit, operationally defined criteria to determine the nature or the timing of the various activities to be undertaken. Consider, for example, the fact that the evidence uncovered during the course of an initial ATSDR health assessment (*2*) may serve as the basis for a wide range of recommendations, including the initiation of further pilot research or a full-scale epidemiological study, the implementation of an intervention program, or some combination of all of the above. At the present time, it is not at all clear how these various alternatives should be evaluated within the context of specific health risk situations, a dilemma that inevitably results in *ad hoc* (or case-by-case) sorts of decision making, which all too often places undue emphasis on unscientific, extraneous, or momentary considerations. This potential for a less than rational expenditure of valuable manpower and resources is magnified when, as is often the case, the investigation of a potentially hazardous case must take place in a highly charged public atmosphere characterized by deeply felt emotions of anger, suspicion, and fear. It might even be suggested that *ad hoc* styles of decision making, since they are open to such a broad range of potential influences, may serve to further stimulate public suspicion and feelings of anger, in turn, making it even more difficult for public health officials to carry out their duties in a fully reasonable and efficient manner.

A Model Standardized Risk Assessment Protocol

The SRAP was designed as a model protocol for dealing with the types of situations described previously. The SRAP would come into use immediately following the identification of a potentially hazardous waste site and might be updated on several occasions during the investigatory phase of work. Underlying the SRAP is the action-oriented assumption that the primary goal is to make a rational, consistent, and cost-effective decision about the level of risk to human populations and the most appropriate

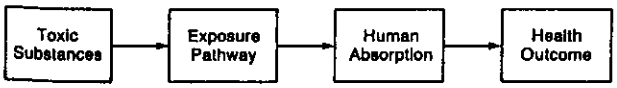

FIGURE 2. Standardized risk assessment protocol significant risk: evidentiary chain (7).

available response at the earliest possible point in the process. In this regard, the SRAP was designed with at least four specific goals in mind: *a*) to organize the available scientific data on a specific site and to highlight important gaps in this knowledge; *b*) to facilitate rational cost-effective decision making about the best distribution of available manpower and resources; *c*) to systematically classify sites roughly according to the level of risk they pose to surrounding human populations; and *d*) to promote an improved level of communication among professionals working in the area of waste site management and between decision makers and the members of the local population.

The SRAP focuses on the degree and patterns of evidence that exist for a significant risk to human populations from exposure to a hazardous waste site. Figure 2 shows the four specific categories of evidence that are considered: evidence that toxic substances exist on the site, evidence that environmental pathways exist for the substances to get offsite, evidence for human absorbtion of the toxic materials, and evidence of relevant health outcomes occurring in the exposed population. It should be noted that, together, these four evidentiary components make up a causal chain linking the toxic substances on a waste site to observed health outcomes in the exposed population. In other words, the SRAP attempts to estimate the extent to which the totality of scientific information available at any particular point in time does or does not support a classic cause-and-effect statement concerning the relevance of the toxic materials on a waste site for the health of the surrounding population.

A SRAP checklist has been developed for rating each one of the four categories of evidence in the causal chain. The content of the checklist was adapted in part, from the S.P.A.C.E. for Health document originally developed by the U.S. Public Health Service (7). The S.P.A.C.E. document, like a number of other proposed rating systems, attempts to produce a single overall priority score as its primary output. In developing our own checklist, we rejected this earlier approach for two important reasons. First, the true meaning of overall priority scores are often deceptive because the evidence from one or two areas of concern may unduly affect the final rating. This creates situations in which the hierarchy of sites, in terms of numerical ratings, may not fit with common sense notions concerning relative levels of risk to human populations. Second, our desire to link levels and patterns of risk to a variety of potential remedial actions led us to focus on the strength of the data for each one of the specific evidentiary components rather than a summary rating. A version of this checklist is provided in Table 1.

The checklist in Table 1 provides a four-point scale (0–3) for each rateable item and a space for indicating missing data. The final ratings for each evidentiary component (i.e., toxic substances, exposure pathways, human absorption, and health outcomes) are binary in character (strong or weak evidence). Ratings of strong or weak evidence are obtained from a specific set of SRAP rules (Fig. 3) that summarize the information collected in the checklist.

The current rules proposed in Figure 3 are weighted in a relatively conservative direction. In order to receive a strong rating, all of the relevant checklist items for an evidentiary component must jointly meet certain minimum standards. Otherwise, a weak rating is assigned to that evidentiary component. To illustrate, a strong rating for the evidence of human absorption would require both a minimum combined score of 5 for the presence of a potentially exposed population and basis of evidence for human exposure/absorption and a minimum score of 2 for levels of substances found through biological sampling. These thresholds, of course, are not fixed, and they may be adjusted to reflect levels of acceptable risk established by responsible expert committees.

Given a completed checklist (i.e., no missing data) and the rules in Figure 3, a final rating of strong or weak may be obtained for the evidence in each component of the risk assessment protocol. These final ratings will produce 1 of 16 possible outcomes (Fig. 4) or patterns of risk. A site, for example, that has strong ratings for both toxic substances and exposure pathways, and weak or indeterminate (i.e., incomplete data) ratings for human absorption and health outcomes would get at least an interim rating of site class 13. In the case of the checklist items having missing data, further investigations regarding human absorption and/or health outcomes might change the initial site class from a 13 to a 14, 15, or, perhaps, even to a 16. Figure 4 also shows how these 16 site classes can be given an action level rating of 0 to 4 depending on the number of evidentiary components receiving a strong rating.

Figure 5 illustrates how these 16 site classes can be roughly organized according to the level of potential risk to human health and can serve as a basis for planning remedial action. In this figure, the 16 site classes are ordered according their action level and cross-classified by appropriate remedial responses. Notice that these responses range from no further action in the case of an action level of 0 to an intensive program of community intervention in the case of action level 4. With regard to the example of the class 13 site discussed above, its action level would be 2 (strong, strong, weak, weak). In such a case, Figure 5 recommends that the following activities be at least considered by the administrator in charge of work on the site: improve site control to block the further discharge of toxic substances; renew biological and pilot health outcome testing to be sure that toxic substances from the site are not being absorbed at significant levels or promoting identifiable health problems among community residents; and initiate an exposure registry to trace any potential health problems that may appear in exposed individuals at a future date. As noted earlier, the additional evidence from the renewed biological and health outcome investigations may ultimately lead to the recategorization of the site at a higher action level and to the implementation of an even more comprehensive program of community intervention.

In reviewing Figures 3 through 5, it should be kept in mind that the term "weak evidence" does not mean "no evidence." A rating of weak evidence simply means that this risk component does not reach the highest level of concern. When planning potential remedial action the content of the information regarding each component with a weak rating should be carefully considered on an individual basis.

Table 1. SRAP checklist (7).

1. Hazardous site

1.a) Documentation of the presence of a hazardous site
- 0 = Uncorroborated allegations
- 1 = Historical records
- 2 = Observation of waste release
- 3 = Laboratory confirmation
- 9 = No data/unknown

1.b) Toxicity of the five most hazardous substances on site (Appendix, Tables A-1 and A-2)
- 0 = None
- 1 = Low
- 2 = Medium
- 3 = High
- 9 = No data/unknown

1.c) Quantity of the five most hazardous substances on site (Appendix, Table A-3)
- 0 = None
- 1 = Low
- 2 = Medium
- 3 = High
- 9 = No data/unknown

1.d) Persistence of five most hazardous chemicals on site (Appendix, Tables A-2 and A-4)
- 0 = None
- 1 = Low
- 2 = Medium
- 3 = High
- 9 = No data/unknown

1.e) Concentration of five most hazardous chemicals on site
- 0 = At background levels
- 1 = Above background levels
- 2 = Greatly exceeds background levels
- 3 = Significant harm potential
- 9 = No data/unknown

1.f) Site management and substance containment (Appendix, Tables A-5 and A-6).
- 0 = Total control
- 1 = Adequate control
- 2 = Inadequate control
- 3 = Uncontrolled
- 9 = No data/unknown

1.g) Potential for direct access to site
- 0 = No direct access
- 1 = Occasional individual access
- 2 = Small population (< 100) with intermittent access
- 3 = Large population with repeated direct access
- 9 = No data/unknown

2. Exposure potential of environmental pathways

2.a) Groundwater (Appendix, Table A-7)
- 0 = None
- 1 = Low
- 2 = Medium
- 3 = High
- 9 = No data/unknown

2.b) Surface water (Appendix, Tables A-8 and A-9)
- 0 = None
- 1 = Low
- 2 = Medium
- 3 = High
- 9 = No data/unknown

2.c) Air
- 0 = No suspected releases
- 1 = Rare reported releases, no apparent effects
- 2 = Intermittent releases, vague or infrequent complaints
- 3 = Repeated releases at levels that exceed standards, frequent major complaints
- 9 = No data/unknown

2.d) Deposition on (in) soil off site
- 0 = Absent or at background levels
- 1 = Above background levels
- 2 = Greatly exceeds background levels
- 3 = Significant harm potential
- 9 = No data/unknown

2.e) Presence in food chain
- 0 = Absent or at background levels
- 1 = Moderate increase over background levels, below FDA standards
- 2 = At or near FDA standards
- 3 = Significantly above FDA standards
- 9 = No data/unknown

3. Potential for human exposure absorbtion

3.a) Presence of potentially exposed population
- 0 = No people within 1 mile of site or relevant pathway
- 1 = People within 1 mile but not within 200 yards of site or relevant pathway
- 2 = Small number of people (< 100) in immediate vicinity of site or pathway
- 3 = Large number of people in immediate vicinity of site or relevant pathway
- 9 = No data/unknown

3.b) Basis of evidence for human exposure/absorption
- 0 = Unfounded allegations
- 1 = Historical records
- 2 = Highly suggestive data from environmental testing
- 3 = Results of biological sampling and/or presence of characteristic illness(es) for relevant exposure
- 9 = No data/unknown

3.c) Levels of substances found through biological sampling
- 0 = Substances not detected or at background levels
- 1 = Small, probably insignificant elevation over background levels
- 2 = Significant elevation over background levels, clinical effects uncertain
- 3 = Exceeds background levels with significant potential for illness
- 9 = No data/unknown

4. Health effects in the exposed population

4.a) Allegations/reports of health effects
- 0 = No allegations or reports
- 1 = Vague, nonspecific and poorly characterized complaints
- 2 = Specific, well-documented reports, but of dubious relevance to exposure under study
- 3 = Solid reports of relevant effects for exposure under study
- 9 = No data/unknown

4.b) Results of clinical or epidemiological studies conducted
- 0 = Sound study with negative results
- 1 = Preliminary or pilot study with negative or inconclusive results
- 2 = Preliminary or pilot study with positive findings
- 3 = Scientifically sound epidemiological study with positive significant findings
- 9 = No data/unknown

4.c) Expectation of current acute or short-term health effects
- 0 = None expected
- 1 = Small expectation
- 2 = Moderate expectation
- 3 = High expectation
- 9 = No data/unknown

4.d) Expectation of future chronic or long-term health effects
- 0 = None expected
- 1 = Small expectation
- 2 = Moderate expectation
- 3 = High expectation
- 9 = No data/unknown

4.e) Severity of public health impact of presumed health effects
- 0 = Negligible
- 1 = Minimal health effects, but widespread
- 2 = Potentially severe effects, but uncommon
- 3 = Severe health effects, with widespread impact
- 9 = No data/unknown

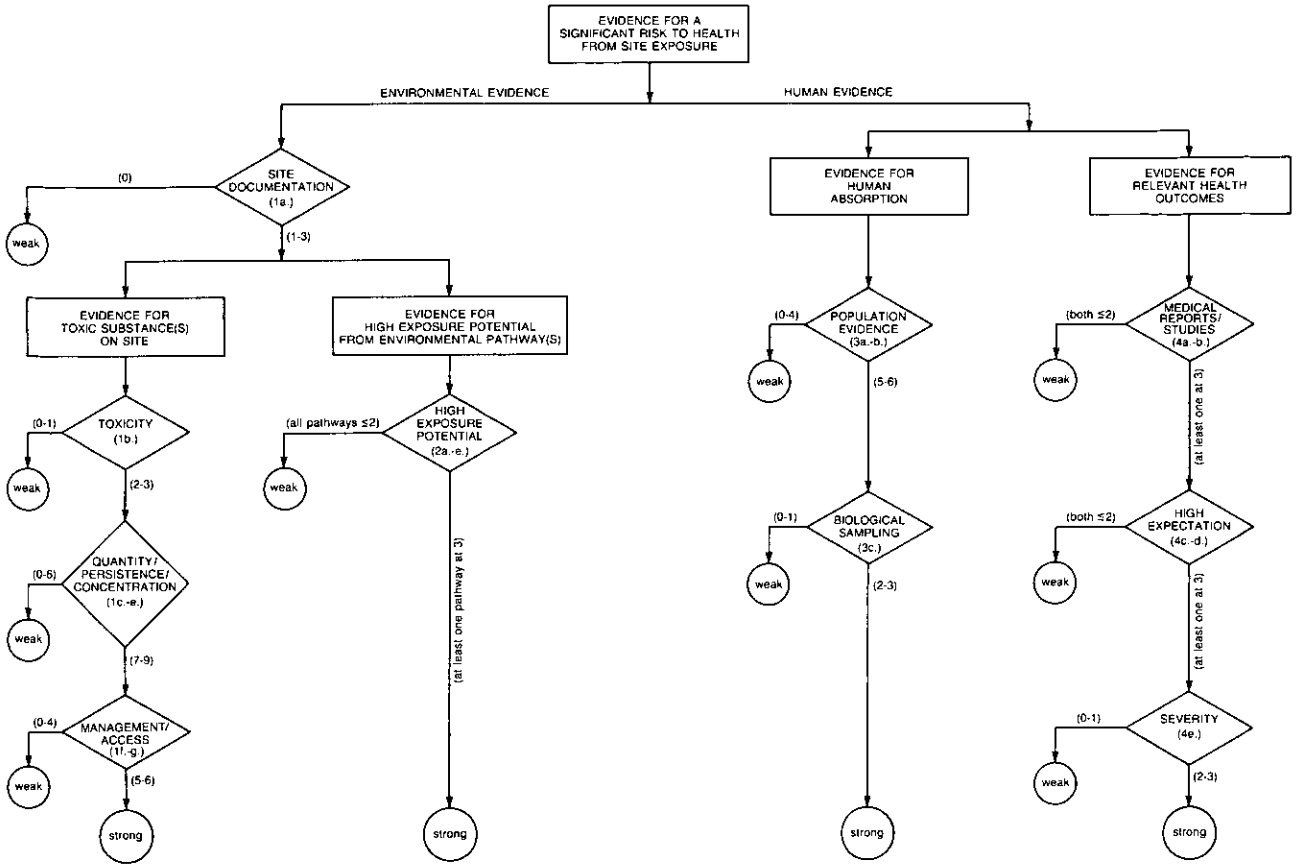

FIGURE 3. Operational rules for summarizing SRAP checklist items.

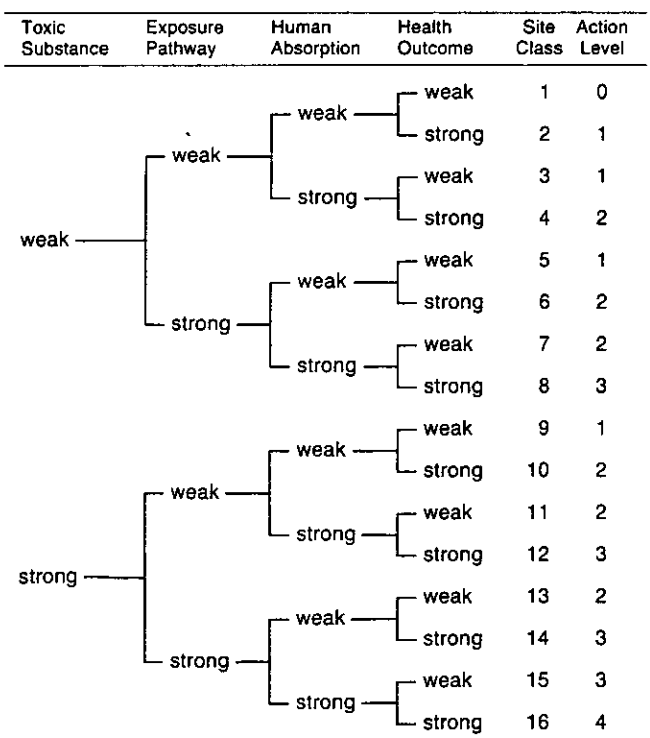

FIGURE 4. Possible SRAP outcomes and action levels.

This checklist approach was designed to be flexible in nature and to be filled out on more than a single occasion during the investigative phase of work. Within the context of the investigative phase, the checklist serves as both a mnemonic and a planning device, ensuring the comprehensiveness of the health risk assessment procedure and systematically highlighting important gaps in the available data.

Under the model developed here, the fundamental goal of the investigatory phase of work should be to complete, to the extent possible, the full health risk assessment procedure for a given site. Ideally, the work in this phase continues until sufficient information is collected to determine whether or not remedial action is required and, if so, the kind of intervention program that is most appropriate to the situation.

Once a full set of ratings of this kind has been completed, the agency staff has a rational basis for assessing the level of potential risk to human health involved in a specific release and deciding upon the most appropriate recommendations to be made in a given situation. Even if a limited amount of data on the checklist remains unknown or if the missing information is confined to a single evidentiary component (e.g., human absorption), it still may be possible to make decisions concerning initial remedial activities on the basis of the data collected in other components of the checklist (e.g., substance, exposure pathway, and health outcomes) while planning further investigatory

	Outcome															
Toxic Substance	W	W	W	W	S	W	W	W	S	S	S	W	S	S	S	S
Exposure Pathway	W	W	W	S	W	W	S	S	S	W	W	S	S	S	W	S
Human Absorption	W	W	S	W	W	S	W	S	W	S	W	S	S	W	S	S
Health Outcome	W	S	W	W	W	S	S	W	W	W	S	S	W	S	S	S
Possible Responses / Action Level	0	1	1	1	1	2	2	2	2	2	2	3	3	3	3	4
No Further Action at Present Time	•			•												
Reassess at Future Date				•												
Improve Site Control					•				•	•	•					
Search for Alternate Exposure Source		•	•			•	•					•				
Renewed Environmental Testing		•	•			•				•	•				•	
Renewed Biological Testing							•		•		•			•		
Pilot Health Outcome or Epid. Studies								•	•	•			•			
Risk Analysis													•			•
Establish Exposure Registry			•					•	•	•	•	•	•	•	•	•
Reduce or Eliminate Exposure								•				•	•	•	•	•
Health Surveillance						•	•				•	•		•	•	•
Treat Affected Residents						•	•				•	•		•	•	•

FIGURE 5. SRAP action levels and responses. W, weak; S, strong.

activities. For example, if strong evidence were available concerning both a poorly controlled toxic substance on a site and the occurrence of relevant health outcomes in a nearby population and weak but still significant evidence regarding an exposure pathway, it probably would not be necessary to await the results of human testing before beginning to plan an intervention program.

Summary and Conclusions

It should again be emphasized that the standardized risk assessment protocol outlined in this paper is simply a model system. It was constructed to illustrate the kind of procedure that might be developed to reduce the *ad hoc* quality that characterizes much of the decision making that occurs with regard to hazardous waste sites. In this sense, the underlying message of this paper is the importance of developing some type of generally accepted, scientifically defensible procedure for classifying toxic waste sites and selecting remedial activities appropriate to the established health risks to human populations.

A standardized protocol of the type presented permits an administrator to systematically answer two critical questions involved in the investigation of any potentially hazardous toxic waste site: Has all the information required for a complete health risk assessment been collected? Does the information that has been collected support a specific recommendation of further action in this case? A protocol of this sort also provides a simple system that classifies sites roughly according to the level of health risk posed to human populations and provides guidelines that relate patterns of risk to available types of remedial activities. The flexible nature of the system permits a site's classification to be updated as new evidence is obtained and allows it to serve as a means of facilitating ongoing communication with other involved professionals, as well as with concerned members of the general public.

Finally, it is our belief that the existence this kind of standardized method for the classification of hazardous wastes stites, that is, one that logically relates patterns of health risk to potential ameliorative actions, may play an important role in reducing or controlling expressed levels of public anger and suspicion. If potentially exposed communities perceive that public health officials have standardized and reliable methods for assessing the extent of the health risks posed by hazardous waste sites, and if the results of such investigations can be communicated to the public on a routine and timely basis, it may be possible in the future to achieve improved public cooperation and confidence, and to promote an atmosphere more conducive to the conduct of the scientific activities necessary to measure true potential risks from the release of toxic substances.

Appendix

SRAP Checklist Tables

In general, substances in Table A-1 classified as having slight toxicity produce changes in the human body that are readily reversible and disappear following termination of exposure, either with or without medical treatment. Those substances classified as having moderate toxicity may produce irreversible as well as reversible changes in the human body. These changes are not of such severity as to threaten life or to produce serious physical impairment.

Assign containment in Table A-5 a value of 0 if all the hazardous substances at the facility are underlaid by an essentially nonpermeable surface (natural or artificial) and adequate leachate collection systems and diversion systems are present or if there is no groundwater in the vicinity. The value 0 does not indicate absence of risk. Rather, 0 indicates a significantly lower relative risk when compared with more serious sites on a national level. Otherwise, evaluate the containment for each of the different means of storage or disposal at the facility, using the guidelines in Table A-5.

Assign containment in Table A-6 a value of 0 if all the waste at the site is surrounded by diversion structures that are in sound condition and adequate to contain all runoff, spills, or leaks from the waste or if intervening terrain precludes runoff from entering surface water. Otherwise, evaluate the containment for each of the different means of storage or disposal at the site and assign a value as outlined in Table A-6.

In Table A-7, check the applicable rating scale level for each rating factor listed in the left column. (You will need to refer to Table A-5 to determine which levels to check for the rating factor "containment.") Considering the interrelationships of the rating factors and the level checked for each one determine and overall level (0, 1, 2, or 3) for exposure potential from the site through groundwater.

Site slope and intervening terrain are indicators of the potential for contaminated runoff or spills at a site to be transported to surface water. The site slope is an indicator of the potential for runoff or spills to leave the site. Intervening terrain refers to the average slope of the shortest path that would be followed by runoff between the site boundary and the nearest downhill surface water. Table A-8 shows values assigned to various combinations of slope conditions. Transfer the value applicable to a particular site to Table A-9 to determine the overall exposure potential from the site through surface water.

In Table A-9, check the applicable rating scale level for each rating factor listed in the left column. (You will need to refer to Tables A-6 and A-8 to determine which levels to check for the rating factors "containment" and "site slope and intervening terrain.") Considering the interrelationships of the rating factors and the level check for each one, determine an overall level (0, 1, 2, or 3) for exposure potential from the site through surface waters.

Table A-1. Sax toxicity ratings (7–9).[a]

0: No toxicity (none)

Materials that cause no harm under any conditions of normal use. Materials that produce toxic effects on humans only under the most unusual conditions or by overwhelming dosage.

1: Slight toxicity (low)

Acute local

Materials that on single exposures lasting seconds, minutes, or hours cause only slight effects on the skin or mucous membranes regardless of the extent of the exposure.

Acute systemic

Materials that can be absorbed into the body by inhalation, ingestion, or through the skin and produce only slight effects following single exposure lasting seconds, minutes, or hours, or following ingestion of a single dose regardless of the quantity absorbed or the extent of exposure.

Chronic local

Materials that on continuous or repeated exposures extending over periods of days, months, or years cause only slight and usually reversible harm to the skin or mucous membranes. The extent of exposure may be great or small.

2: Moderate toxicity (mod)

Acute local

Materials that on single exposure lasting seconds, minutes, or hours cause moderate effects on the skin or mucous membranes. These effects may be the result of intense exposure or a matter of seconds or moderate exposure for a matter of hours.

Acute systemic

Materials that can be absorbed into the body by inhalation, ingestion, or through the skin and produce moderate effects following single exposures lasting seconds, minutes, or hours, or following ingestion of a single dose.

Chronic local

Materials that on continuous or repeated exposure extending over periods of days, months, or years cause moderate harm to the skin or mucous membranes.

Chronic systemic

Materials that can be absorbed into the body by inhalation, ingestion, or through the skin and produce moderate effects following continuous or repeated exposures extending over periods of days, months, or years.

3: Severe toxicity (high)

Acute local

Materials that on single exposure lasting seconds or minutes cause injury to skin or mucous membranes of sufficient severity to threaten life or to cause permanent physical impairment or disfigurement.

Acute systemic

Materials that can be absorbed into the body by inhalation, ingestion, or through the skin and can cause injury of sufficient severity to threaten life following a single exposure lasting seconds, minutes, or hours, or following ingestion of a single dose.

Chronic local

Materials that on continuous or repeated exposures extending over periods of days, months, or years can cause injury to skin or mucous membranes of sufficient severity to threaten life or cause permanent impairment, disfigurement, or irreversible change.

Chronic systemic

Materials that can be absorbed into the body by inhalation, ingestion or through the skin and can cause death or serious physical impairment following continuous or repeated exposures to small amounts extending over periods of days, months, or years.

[a]Numbered toxicity ratings are from Sax (*8*). Toxicity ratings in parentheses are from Sax (*9*).

Table A-2. Characteristics ratings for some common chemicals (*7*).

Chemical/compound	Toxicity (*8*)[a]	Persistence (*10*)	Ignitability (*11*)	Reactivity (*11*)
Acetaldehyde	3	0	3	2
Acetic acid	3	0	2	1
Acetone	2	0	3	0
Aldrin	3	3	1	0
Ammonia, anhydrous	3	0	1	0
Aniline	3	1	2	0
Benzene	3	1	3	0
Carbon tetrachloride	3	3	0	0
Chlordane	3	3	0[b]	0[b]
Chlorobenzene	2	2	3	0
Chloroform	3	3	0	0
Cresol-O	3	1	2	0
Cresol-(*meta, para*)	3	1	1	0
Cyclohexane	2	2	3	0
Endrin	3	3	1	0
Ethyl benzene	2	1	3	0
Formaldehyde	3	0	2	0
Formic acid	3	0	2	0
Hydrochloric acid	*3*	*0*	*0*	*0*
Isopropyl ether	3	1	3	1
Lindane	3	3	1	0
Methane	1	1	3	0
Methyl ethyl ketone	2	0	3	0
Methyl parathion in xylene solution	3	0[c]	3	2
Naphthalene	2	1	2	0
Nitric acid	3	0	0	0
Parathion	3	0[c]	1	2
PCB	3	3	0[c]	0[c]
Petroleum, kerosene (fuel oil no. 1)	3	1	2	0
Phenol	3	1	2	0
Sulfuric acid	3	0	0	2
Toluene	2	1	3	0
Trichlorobenzene	2	3	1	0
α-Trichloroethane	2	2	1	0
Xylene	2	1	3	0

[a]The highest rating listed under each chemical in Sax (*8*) is used.
[b]Professional judgment based on information contained in the U.S. Coast Guard CHRIS Hazardous Chemical Data (*12*).
[c]Professional judgment based on existing literature.

Table A-3. Quantity of hazardous substances (*7*).[a]

Tons in cubic yards	Numbers of drums	Applicable criterion level
0	0	0
1–125	1–500	1
126–1250	501–5000	2
> 1250	> 5000	3

[a]On occassion it may be necessary to convert data to a common unit to combine them. In such cases, 1 ton = 1 cubic yard = 4 drums, and for the purposes of converting bulk storage, 1 drum = 50 gallons.

Table A-4. Environmental persistence (biodegradability) of some organic compounds (7).

Value 3: highly persistent compounds		Value 2: persistent compounds	Value 1: somewhat persistent compounds	Value 0: nonpersistent compounds
Aldrin	Pentachlorobiphenyl	Acanaphthylene	Acetylene dichloride	Acetaldehyde
Benzopyrene	Pentachlorophenol	Atrazine	Behenic acid, methylester	Acetic acid
Benzothiazole	1,1,3,3-Tetrachloroacetone	(Diethyl)atrazine	Benzene	Acetone
Benzothiophene	Tetrachlorophenyl	Barbital	Benzene sulfonic acid	Acetophenone
Benzyl butyl phythalate	Thiomethylbenzothiazole	Borneol	Butyl benzene	Benzoic acid
Bromochlorobenzene	Trichlorobenzene	Bromobenzene	Butyl bromide	Di-isobutyl carbinol
Bromoform butanal	Trichlorobiphenyl	Camphor	*e*-Caprolactam	Docosane
Bromphenyl phyntyl ether	Trichlorofluormethane	Chlorobenzene	Carbon disulfide	Eicosane
Chlordane	2,4,6-Trichlorophenol	1,2-*bis*-Chloroethoxy ethane	*o*-Cresol	Ethanol
Chlorohydroxy-benzephenone	Triphenyl phosphate	*b*-Chloroethyl methyl ether	Decane	Ethylamine
bis-Chloroisoprophyl ether	Bromodichloromethane	Chloromethyl ether	1,2-Dichloroethane	Hexadecane
m-Chloronitrobenzene	Bromoform	Chloromethyl ethyl ether	Limonene	Methanol
DDE	Carbon tetrachloride	3-Chlorphyridine	Methyl ester of ligocenic acid	Methyl benzoate
DDT	Chloroform	Di-*t*-butyl-*p*-benzoquinone	Methane	3-Methyl butanol
Dibromobenzene	Chloromochloromethane	Dichloroethyl ether	2-Methyl-5-ethylpyridine	Methyl ethyl ketone
Dibutyl phthalate	Dimethyl phthalate	Dihyrocarvone	Methyl naphthalene	2-Methylpropanol
1,4-Dichlorobenzene	4,6-Dinitro-2-aminophenol	Dimethyl sulfoxide	Methyl palmitate	Octadecane
Dichlorodifluoroethane	Dipropyl phythalate	2,6-Dinitrotoluene	Methyl phenyl carbinol	Pentadecane
Dieldrin	Endrin	*cis*-2-Ethyl-4-methyl-1,3-dioxolane	Methyl stearate	Pentanol
Diethyl phthalate	Dibromodichloroethane	*trans*-2-Ethyl-4-methyl-1,3,-dioxolane	Nonane	Propanol
Di-(2-ethylhexyl)phthalate	Tetrachloroethane	Guaiacol	1,2-Dimethoxy benzene	Propylamine
Dibexyl phthalate	1,1,2-Trichloroethane[a]	2-Hydroxyadiponitrile	1,3-Dimethyl naphthalene	Tetradecane
Di-isobutylphthalate		Iaophorone	1,4-Dimethyl phenol	*n*-Tridecane
Heptachlor		Indene	Dioctyl adipate	*n*-Undecane
Heptachlor epoxide		Isoborneal	*n*-Decane	
1,2,3,4,5,7,7-Heptachloronobomane		Isoprophenyl-r-isopropyl benzene	Ethyl benzene	
Hexachlorobenzene		2-Methoxy biphenyl	2-Ethyl-*n*-hexane	
Hexachloro-1,3-butadiene		Methyl biphenyl	*o*-Ethyltoluene	
Hexachlorocyclohexane		Methyl chloride	Isodecane	
Hexachloroethane		Methylene chloride	Isoprophyl benzene	
Methyl benzothiazole		Methylindene	Octane	
		Nitroanisole	Octyl chloride	
		Nitrobenzene	Pentane	
		1,1,2-Trichloroethylene	Phenyl benzoate	
		Trimethyl-trioxo-hexahydro	Phthalic anhydride	
		Triazine iosmer	Propylbenzene	
			1-Terpineol	
			Toluene	
			Vinyl benzene	
			Xylene	

[a]From JRB Associates, Inc. (*10*).

Table A-5. Containment value for groundwater route (7).

Criteria	Assigned value
Surface impoundment	
Sound run-on diversion structure, essentially nonpermeable liner (natural or artificial) compatible with the waste, and adequate leachate collection system	0
Essentially nonpermeable compatible liner with no leachate collection system; or inadequate freeboard	1
Potentially unsound run-on diversion structure or moderately permeable compatible liner	2
Unsound run-on diversion structure; no liner or incompatible liner	3
Containers	
Containers sealed and in sound condition, adequate liner, and adequate leachate collection system	0
Containers sealed and in sound condition, no liner or moderately permeable liner	1
Containers leaking, moderately permeable liner	2
Containers leaking and no liner or incompatible liner	3
Piles	
Piles uncovered and waste stabilized, or piles covered, waste unstabilized and essentially nonpermeable liner	0
Piles uncovered, waste unstabilized, moderately permeable liner, and leachate collection system	1
Piles uncovered, waste unstabilized, moderately permeable liner, and no leachate collection system	2
Piles uncovered, waste unstabilized, and no liner	3
Landfill	
Essentially nonpermeable liner, liner compatible with waste, and adequate leachate collection system	0
Essentially nonpermeable compatible liner, no leachate collection system, and landfill surface precludes ponding	1
Moderately permeable, compatible liner, and landfill surface precludes ponding	2
No liner or incompatible liner; moderately permeable compatible liner, landfill surface encourages ponding; no run-on control	3

Table A-6. Containment values for surface water route (7).

Criteria	Assigned value
Surface impoundment	
Sound diking or diversion structure, adequate freeboard, and no erosion evident	0
Sound diking or diversion structure, but inadequate freeboard	1
Diking not leaking, but potentially unsound	2
Diking unsound, leaking, or in danger of collapse	3
Containers	
Containers sealed, in sound condition, and surrounded by sound diversion or containment system	0
Containers sealed and in sound condition, but not surrounded by sound siversion or containment system	1
Containers leaking and diversion or containment structures potentially unsound	2
Containers leaking, and no diversion or containment structures or diversion structures leaking or in danger of collapse	3
Waste piles	
Piles are covered and surrounded by sound diversion or containment system	0
Piles covered, wastes unconsolidated, diversion or containment system not adequate	1
Piles not covered, wastes unconsolidated, and diversion or containment system potentially unsound	2
Piles not covered, wastes unconsolidated, and no diversion or containment or diversion system leaking or in danger of collapse	3
Landfill	
Landfill slope precludes runoff, landfill surrounded by sound diversion system, or landfill has adequate cover material	0
Landfill not adequately covered and diversion system sound	1
Landfill not covered and diversion system potentially unsound	2
Landfill not covered and no diversion system present, or diversion system unsound	3

Table A-7. Exposure potential through groundwater.

	Rating scale levels			
Rating factors	0	1	2	3
Depth to water table	> 150 feet	76–150 feet	21–75 feet	0–20 feet
Depth to aquifer of concern (may be same as above)	> 150 feet	76–150 feet	21–75 feet	0–20 feet
Net precipitation	< −10 in./year	−10 to 5 in./year	5–15 in./year	> 15 in./year
Permeability of unsaturated zone	Clay, compact till, shale; unfractured metamorphic and igneous rocks $<10^{-7}$ cm/sec[a]	Silt, loess, silty clays, silty loams, clay loams; less permeable limestone, dolomites, and sandstone; moderately permeable till. $<10^{-5}>10^{-7}$ cm/sec[a]	Fine sand and silty sand; sandy loams; loamy sands; moderately permeable limestone, dolomites, and sandstone (no karst); moderately fractured igneous and metamorphic rocks, some course till. $<10^{-3}>10^{-5}$ cm/sec[a]	Gravel, sand; highly fractured igneous and metamorphic rocks; permeable basalt and lavas; karst limestone and dolomite. $>10^{-3}$ cm/sec[a]
Permeability of aquifer(s) of concern	Clay, compact till, shale; unfractured metamorphic and igneous rocks $<10^{-7}$ cm/sec[a]	Silt, loess, silty clays, silty loams, clay loams; less permeable limestone, dolomites, and sandstone; moderately permeable till. $<10^{-5}>10^{-7}$ cm/sec[a]	Fine sand and silty sand; sandy loams; loamy sands; moderately permeable limestone, dolomites, and sandstone (no karst); moderately fractured igneous and metamorphic rocks, some course till. $<10^{-3}>10^{-5}$ cm/sec[a]	Gravel, sand; highly fractured igneous and metamorphic rocks; permeable basalt and lavas; karst limestone and dolomite. $>10^{-3}$ cm/sec[a]
Permeability of confining layers below water table but above aquifer of concern	Clay, compact till, shale; unfractured metamorphic and igneous rocks $<10^{-7}$ cm/sec[a]	Silt, loess, silty clays, silty loams, clay loams; less permeable limestone, dolomites, and sandstone; moderately permeable till. $<10^{-5}>10^{-7}$ cm/sec[a]	Fine sand and silty sand; sandy loams; loamy sands; moderately permeable limestone, dolomites, and sandstone (no karst); moderately fractured igneous and metamorphic rocks, some course till. $<10^{-3}>10^{-5}$ cm/sec[a]	Gravel, sand; highly fractured igneous and metamorphic rocks; permeable basalt and lavas; karst limestone and dolomite. $>10^{-3}$ cm/sec[a]
Physical state	Solid, consolidated, or stabilized	Solid, unconsolidated, or unstabilized	Powder or fine material	Liquid, sludge, or gas
Containment[b]				
Groundwater use	Unusable (e.g., extremely saline, extremely low yield)	Commercial, industrial, or irrigation; another water source presently available and usable	Drinking water with alternate unthreatened sources available or commercial, industrial, or irrigation with no other source available	Drinking water with no alternate unthreatened sources available
Distance to nearest well drawing from aquifer of concern	> 3 miles	1.5–3 miles	2000 feet–1.5 miles	< 2000 feet
Population using aquifer of concern for drinking water	0	1–100	101–3000	> 3000

[a] Approximate range of hydraulic conductivity.
[b] Containment level determined by use of Table A-5.

Table A-8. Values for site slope and intervening terrain.

Facility	slope	Intervening terrain, average slope <3%[a]	3–5%	5–8%	>8%	Site in surface water
Facility is closed basin		0	0	0	0	3
Facility has average slope (<3%)		0	1	1	2	3
Average slope (3–5%)		0	1	2	2	3
Average slope (5–8%)		0	2	2	3	3
Average slope (>8%)		0	2	3	3	3

[a]Terrain average slope <3% or site separated from water body by areas of higher elevation.

Table A-9. Exposure potential through surface waters.

Rating factors	Rating scale levels 0	1	2	3
Site slope and intervening terrain[a]				
1 year 24 hr rainfall	< 1 in.	1 – 2 in.	2.1 – 3 in.	> 3 in.
Distance to nearest surface water	> 2 miles	1 – 2 miles	1000 feet – 1 mile	< 1000 feet
Physical state	Solid, consolidated, or stabilized	Solid, unconsolidated, or stabilized	Powder or fine material	Liquid, sludge, or gas
Containment[b]				
Surface water use	Not currently used	Commercial or industrial	Irrigation, economically important resources (e.g., shellfish), commercial food preparation, or recreation (e.g., fishing, boating, swimming)	Drinking water
Population using surface water of concern for drinking	0	1 – 100	101 – 3000	> 3000

[a]Site slope and intervening level determined by the use of Table A-8.
[b]Containment level determined by use of Table A-6.

This research was supported in part by a contract between the University of Pittsburgh and the Chemical Manufacturers Association.

REFERENCES

1. EPA. National oil and hazardous substances contigency plan. Fed. Reg. 47: 31180 (1982).
2. ATSDR. Pilot epidemiologic studies to determine relationships between human exposure to hazardous substances and adverse health outcomes. Fed. Reg. 53: 19337 (1988).
3. Marsh, G. M., and Caplan, R. Evaluating health effects of exposure at hazardous waste sites: a review of the state-of-the-art with recommendations for future research. In: Health Effects from Hazardous Waste Sites, (J. Andelman and D. Underhill, Eds.), Lewis Publishers, Chelsea, MI, 1987 pp. 3–80.
4. Marsh, G. M., and Day, R. Decision Making and Quality Control Criteria for the Conduct of Pilot and Epidemiological Studies by ATSDR under SARA Section 110. Report to the Chemical Manufacturers Association. University of Pittsburgh, Graduate School of Public Health, Pittsburgh, PA, April 1988.
5. Comprehensive Environmental Response, Compensation and Liability Act of 1980. Pub. L. 96-510, Dec. 11, 1980, 94 Stat. 2767.
6. Superfund Amendments and Reauthorization Act of 1986. Pub. L. 99-499, Oct. 17, 1986, 100 Stat. 1613.
7. US PHS. S.P.A.C.E. for Health: A System for Prevention, Assessment and Control of Exposures and Health Effects from Hazardous Sites. U.S. Public Health Service, Washington, DC, April 1983.
8. Sax, N. L. Dangerous Properties of Industrial Materials, 4th ed. Van Nostrand Rheinhold Co., New York, 1976.
9. Sax, N. L. Dangerous Properties of Industrial Materials, 5th ed. Van Nostrand Rheinhold Co., New York, 1979.
10. JRB Associates, Inc. Methodology for Rating the Hazard Potential of Waste Disposal Sites. May 1980.
11. National Fire Protection Association. National Fire Codes, Vol. 13, No. 49, 1977. National Fire Association, Boston, MA.
12. U.S. Coast Guard. CHRIS: Chemical Hazards Response Information System. Part 2, Hazardous Chemical Data. U.S. Government Printing Office, Washington, DC, 1978.