

APPENDIX A
SUMMARIES OF RANKING AND SCORING SYSTEMS

System Summary 1

Toxics Release Inventory (TRI) Environmental Indicators Methodology

References

Abt Associates, Inc. (1992). Toxics Release Inventory Environmental Indicators Methodology. (Draft Report). By Abt Associates, for U.S. Environmental Protection Agency (EPA) Office of Pollution Prevention and Toxics.

Developed for Use by: EPA Office of Pollution Prevention and Toxics

Purpose: "The ultimate goal of the indicator effort is to devise a measure that reflects the impacts of chemical releases and transfers, which can be used to assess progress in reducing these impacts over time"

Chemicals Addressed: TRI chemicals

Summary of Method or Algorithm

Each indicator (e.g. for human health chronic impacts) is determined by 4 components:

- the quantity of the chemical released or transferred
- a toxicity adjustment
- an adjustment reflecting the size of the potentially exposed population, and
- an exposure potential adjustment

"Separate assessments are made for each unique combination of a chemical, facility and release medium. For each of these releases or transfers, one develops an indicator 'element': a unitless value proportional to the potential impact of each specific release or transfer." The TRI indicator is the sum of all indicator elements.

An indicator element is calculated for human health and ecological impacts according to the following algorithms:

human health chronic indicator

Indicator element $_{i,j,k}$ = Toxicity weight $_{i,j}$ x Exposure weight $_{i,j,k}$ x Adjusted population $_{jk}$, for chemical $_i$; facility $_j$; and medium $_k$

Ecological chronic indicator

Indicator element $_{i,j,k}$ = Toxicity weight $_{i,j}$ * Exposure weight $_{i,j,k}$, for chemical $_i$; facility $_j$; and medium $_k$

Simple sum of component scores: $I = S_1 + S_2 + S_3 \dots S_R$

where I = TRI indicator of interest

S = facility-chemical-medium specific indicator element

Then normalize simple sum to a base year to track progress

System Summary 1, continued

Criteria, Subcriteria, and Endpoints

Mammalian Toxicity

Carcinogens

Weight of evidence

- EPA Risk Assessment Guidelines
- TSCA Chemical Scoring System Category

Potency

- EPA q_1 *
- ED₁₀

Non-carcinogens

RfDs when available, use the following if RfDs are not available

WOE for

- genotoxicity
- developmental effects
- mutagenicity (EPA)

- "Similar weighting systems need to be developed for neurotoxicity, reproductive toxicity and other chronic toxicity endpoints"

Potency (all human-adjusted)

- minimum effective dose (MED)
- lowest-observable-adverse-effect level (LOAEL)
- no-observable-adverse-effect level (NOAEL)

Aquatic Toxicity

Aquatic toxicity category

- life cycle or chronic NOAEL
- LC₅₀
- acute Ambient Water Quality Criteria (AWQC)
- chronic AWQC

Bioaccumulation

- water solubility (mg/L)
- log K_{ow}
- BCF

Human Exposure Potential

- surrogate dose (mg/kg day)
- uncertainty estimate

Ecological Exposure

- estimated ambient water concentration

Population Size

Data Selection Approach

Note that this is a draft report. There are issues related to the specific methodology of the developed indicators and the development of additional indicators that are not yet resolved. In general, the final toxicity weight will be the highest weight it receives among all of the endpoints considered. Exposure is modelled, and the system works with data gaps. SARs may be used in some cases.

System Summary 2

The CERCLA 104 Priority List of Hazardous Substances That Will be the Subject of Toxicological Profiles

References

Agency for Toxic Substances and Disease Registry (1992). *Support Document: The CERCLA 104 Priority List of Hazardous Substances That Will Be The Subject of Toxicological Profiles*. U.S. Public Health Service, Department of Health and Human Services, Washington, D.C.

Developed for Use by: ATSDR and EPA

Purpose

As required by CERCLA section 104, the ATSDR and EPA must prepare a list, in order of priority, of substances, that are most commonly found at NPL facilities and which are determined to pose the most significant potential threat to human health. Substances on the priority list are candidates for toxicological profiles prepared by the ATSDR.

Chemicals Addressed: Over 700 substances found at three or more NPL sites

Summary of Method or Algorithm

Scores are assigned to every chemical in three categories including toxicity, frequency of occurrence at NPL sites and potential human exposure. The final score is the sum of the three scores:

Total Score = NPL frequency score + Toxicity score + Potential human exposure score
(1800) (600) (600) (300 conc) + (300 exposure)

System Summary 2, continued

Criteria, Subcriteria, and Endpoints

Frequency of Occurrence at NPL Sites

- Frequency as reported in ATSDR's HazDat database

Toxicity

- Reportable quantity (RQ), or
- Toxicity/Environmental Score (TES); based on RQ methodology, including:
 - Ignitability/Reactivity
 - Aquatic Toxicity
 - LC₅₀
 - Mammalian Toxicity
 - Oral LD₅₀
 - Dermal LD₅₀ or
 - Inhalation LC₅₀
 - Chronic Toxicity
 - minimum effective dose (MED)
 - rating values (R_v) 1 - 10 based on severity of effect
 - Carcinogenicity
 - EPA weight-of-evidence
 - Potency (high, medium, low)
 - Biodegradation/Hydrolysis/Photolysis Adjustment

Potential for Human Exposure

Concentration

- theoretical daily dose (from measured site concentrations in HazDat database)

Exposure

- Exposure to or potential exposure to contaminant
- Exposure to or potential exposure to medium containing contaminant

Data Selection Approach

All data are required. In the absence of an RQ, a toxicity/environmental score (TES) is calculated, based on the RQ methodology. In some cases, TESs are assigned based on the RQs for structurally-similar substances if relevant data are lacking. The RQs and TESs are based on a pool of criteria, with the most conservative value determining the score. Adjustments may be made based on biodegradation, hydrolysis or photolysis.

Potential for human exposure scores are based on available concentration data (or population data in its absence) and a score for exposure or potential exposure to contaminants.

System Summary 3

Existing Chemicals of Environmental Relevance / Beratergremium für Umweltrelevante Altstoffe (BUA)

References

Behret, H. (Ed.). (1989). *Existing Chemicals of Environmental Relevance*. GDCh-Advisory Committee on Existing Chemicals of Environmental Relevance. VCH Publishers, New York.

Developed for Use by: Society of German Chemists (GDCh)

Purpose

To select chemicals (60) which must be examined as to whether they warrant regulatory action to be taken, as provided for in 84(6) of the German Chemicals Act.

Chemicals Addressed

13 international lists including organics and inorganics

There are 2 categories of lists:

- 1) chemicals which occur in the environment; and
- 2) chemicals of industrial importance

Summary of Method or Algorithm

The selected chemicals show the highest scores for the following criteria

- Occurrence in the environment (air or water) and
- Degradability (in air or water)

and at least one of the following

- Bioaccumulation potential
- Acute aquatic toxicity
- Acute toxicity to mammals
- Indications of mutagenic or carcinogenic properties

System Summary 3, continued

Criteria, Subcriteria, and Endpoints

Occurrence in environment (concentration or qualitative indication)

- occurrence in water, soil
- occurrence in air

Degradability

- degradability in water (measured or qualitative indication)
- degradability in air (tropospheric half-life or qualitative indication)

Bioaccumulation

- $\log P_{ow}$
- BCF
- qualitative indication

Acute aquatic toxicity

- LC_{50} , fish
- EC_{50} , daphnia
- qualitative indication

Acute mammalian toxicity

- oral LD_{50}
- dermal LD_{50}
- inhalation LC_{50}
- qualitative indication

Indication of Mutagenic/Carcinogenic Properties

- type of effects or qualitative indication (weight-of-evidence ratings not discussed)

Data Selection Approach

A minimum data set is needed, including occurrence, degradability and effects data. Chemicals lacking sufficient data cannot be prioritized, but are rather placed on a "waiting list". However, data for all effects criteria are not necessary due to the selection criteria. Negative scores indicate estimations or suspicion of effects. The scoring procedure follows, in principle, the procedure used by the U.S. Interagency Testing Committee.

System Summary 4

BUA Second Priority List

References

Behret, H. (Ed.). (1989). *Existing Chemicals of Environmental Relevance II, Selection Criteria and Second Priority List*. GDCh-Advisory Committee on Existing Chemicals of Environmental Relevance. VCH Publishers, New York.

Developed for Use by: Society of German Chemists (GDCh)

Purpose

To select existing substances of recognized environmental relevance in response to government authorization contained in 84(6) of the German Chemicals Act.

This is the second list with 75 substances (does not include 60 from first list).

Chemicals Addressed

13 international lists including organics and inorganics

There are 2 categories of lists:

- 1) chemicals which occur in the environment; and
- 2) chemicals of industrial importance

Summary of Method or Algorithm

Priority is given to substances with high effects potential or high environmental exposure if these substances are not degradable in water and air. Two chemical groups are selected.

Group I: substances probably not degradable with high biological effects potential, based on:

- acute aquatic, acute mammalian, or mutagenicity/carcinogenicity; and
- poor degradability in water or air

Group II: substances probably not degradable with high environmental exposure potential, based on:

- occurrence in air and hardly degradable in air
- occurrence in water and biologically non-degradable in water

Selection was further refined based on substance domestic production rate.

System Summary 4, continued

Criteria, Subcriteria, and Endpoints

Occurrence in environment (concentration or qualitative indication)

- occurrence in water, soil
- occurrence in air

Degradability

- degradability in water (measured or qualitative indication)
- degradability in air (tropospheric half-life or qualitative indication)

Bioaccumulation

- log P_{ow}
- BCF
- qualitative indication

Acute aquatic toxicity

- LC_{50} , fish
- EC_{50} , daphnia
- qualitative indication

Acute mammalian toxicity

- oral LD_{50}
- dermal LD_{50}
- inhalation LC_{50}
- qualitative indication

Indication of Mutagenic/Carcinogenic Properties

- type of effects or qualitative indication
(those receiving highest score are further differentiated on weight-of-evidence ratings)

Production in the Federal Republic of Germany (tons/annum)

Data Selection Approach

A minimum data set is needed for Group I selection, including at least one toxicity endpoint (most conservative, of several) and at least one of the degradability endpoints. For Group II selection, one degradability (determined by several methods) and one occurrence data point are necessary. Estimations for some endpoints may be calculated. Negative scores indicate estimations by SAR.

System Summary 5

Region VII Toxics Release Inventory Geographic Risk Analysis System (TIGRAS)

References

Bouchard, D. (1991). *Review of Region VII TRI Strategy*. (Memo, EPA Region VII).

Developed for Use by

Region VII TRI work group ("Friends of TRI")

Purpose

To develop user-friendly tools for relative risk screening based on TRI releases for specified geographic areas. It ranks risk to both human and ecological health from TRI releases.

Chemicals Addressed

TRI chemicals

Summary of Method or Algorithm

Components of TIGRAS (Toxics Release Inventory Geographic Risk Analysis):

1. TRI/GIS interface: the user selects a base map by country or zip code, identifies stressors (currently includes only TRI data) and year or years as well as TRI release media. A map is created.
2. Risk Screening Module: includes human health risk analysis and ecological risk analysis.

Scores for human health and ecological risk are not combined for an overall score.

System Summary 5, continued

Criteria, Subcriteria, and Endpoints

Human health risk analysis

Toxicity (relative toxicity parameter, RTP)

Acute effects

inhalation, non-cancer

- endpoint not specified

ingestion, non-cancer

- reciprocal of 10-day health advisory levels from ODW for a 10-kg child
- adjusted subchronic RfD (could fill data gaps)

Chronic effects

inhalation, cancer

- unit risk factors from IRIS, HEAST

ingestion, cancer

- unit risk factors from IRIS, HEAST

inhalation, non-cancer

- reciprocals of RfCs from IRIS, HEAST

ingestion, non-cancer

- reciprocals of RfDs from IRIS, HEAST or ODW

Loadings

- Relative daily toxic loading (RDTL), where:

$$\text{RDTL} = \text{TRI release} \times \text{RTP}$$

Ecological Risk Analysis (aquatic ecology)

Toxicity (relative toxicity parameter, RTP)

Acute effects

- 48-hr LC_{50} (daphnia, fish)
- LC_{50} , population growth (PGR) or lethality (LET) (algae)

Loadings

- Relative daily toxic loading (RDTL), where:

$$\text{RDTL} = \text{TRI release} \times \text{RTP} / \text{stream volume}$$

Data Selection Approach

All data are not required, but only chemicals with similar data can be compared. Real data are needed to calculate relative toxicity parameters (RTPs) for all toxicity criteria, however, one RDTL will be calculated, and comparison can only be done when RDTLs are calculated from similar RTPs. Therefore data for all toxicity criteria are not required. A data hierarchy is specified for some criteria. Other data for loading (releases) and stream volume are needed. Due to lack of data, human health risk analysis will be used as a surrogate for terrestrial animals.

Candidate Substance List for Bans or Phase-outs

References

Socha, A.C., T. Dickie, & R. Aucoin, R.V. Angelow, P. Kauss, and G. Rutherford (1992). *Candidate Substances List for Bans or Phase-Outs*. Ontario Ministry of the Environment. ISBN 0-7729-9764-0.

Developed for Use by

Ontario's Ministry of the Environment

Purpose

To identify substances released into or present in Ontario's surface waters which pose the greatest hazard, based on their potential to cause adverse impact on the environment.

Chemicals Addressed

800 substances known as the "MISA Primary Group", which includes inorganics, organics and pesticides.

Summary of Method or Algorithm

Chemicals are selected for inclusion on a primary list or one of three secondary lists if certain criteria are met. The primary list is composed of chemicals considered to be:

persistent: $t_{1/2} > 50$ days in water, soil, sediment or sludge;

bioaccumulative: $BCF > 500$ or $4.0 < \log k_{ow} < 7$;

and toxic: Receives highest score in any one toxicity category.

A substance is considered to be toxic if it meets any one criterion on a list of several criteria which generally correspond to a score of 10 from the MOE scoring criteria.

The secondary lists are:

A: toxic and persistent or bioaccumulative

B: persistent and bioaccumulative and toxicity score = 8 in at least one toxicity category

C: persistent or bioaccumulative and toxicity score = 8

System Summary 6, continued

Criteria, Subcriteria, and Endpoints

(Based on MOE scoring criteria)

Persistence

- $t_{1/2}$ in water, sediment or soil

Bioaccumulation

- fish BCF
- $\log k_{ow}$

Toxicity

Acute lethality

- oral LD_{50}
- dermal LD_{50}
- inhalation LD_{50}
- aquatic LC_{50}

Chronic/Subchronic Toxicity

aquatic biota (different genera)

- EC_{50}
- MATC
- NOAC

terrestrial non-mammals (different genera)

- subchronic effects
- chronic effects

plants

for aqueous, air and soil media:

- NOAEL or $\leq 5\%$ effect
- EC_{50} or $> 5 - 50\%$ effect
- $> 50\%$ effect

mammals

oral NOAEL, ≥ 90 days or 28-90 days

inhalation NOAEC, ≥ 90 days or 28-90 days

Teratogenicity

- observed effects (effective dose)

Carcinogenicity

- IARC or EPA Classification

Data Selection Approach

Selected chemicals are considered to be toxic, persistent and bioaccumulative. Toxicity may be determined by any one of several endpoints for acute or chronic toxicity. Data are needed for persistence in water, soil, sediment *or* sludge. Bioaccumulation (BCF) data are essential and may be estimated by $\log k_{ow}$.

Criteria for Identifying High Risk Pollutants

References

Criteria for Identifying High Risk Pollutants. *Environmental Reporter* (pp. 463-465). (BNA)(1991)Bureau of National Affairs, Inc, Washington, D.C.

Developed for Use by: EPA

Purpose

A ranking of hazardous air pollutants is required by some provisions of Section 112 of the Clean Air Act Amendments. It is intended to limit the use of off-setting reductions in emissions of hazardous air pollutants by other hazardous air pollutants.

Chemicals Addressed: Hazardous air pollutants (HAPs)

Summary of Method or Algorithm

The screening analysis evaluates hazardous air pollutants in a three-tiered approach.

Tier I: Selected chemicals for which the available health effects data for a pollutant met certain criteria:

Potential carcinogens

- a) had EPA-approved potency factor
- b) had high concern designation for carcinogenicity potential in CERCLA section 102

Non-carcinogens and carcinogens causing other health effects

- a) had EPA-verified RfD or RfC
- b) had appropriate data from RTECS

Tier II: To determine which of the remaining pollutants merited further analysis, based on standardized risk calculations

Carcinogens

- calculated on acceptable risk 'benchmark' concentration; pollutants are selected if they exceeded the benchmark at 10 tons/year

Non-carcinogens

- modelled ambient concentrations > RfC or RfD by at least 1 order of magnitude
- ambient concentration > LOEL or LD₅₀ / uncertainty factor

Tier III: "Review of nation-wide emissions data"

If one or more sources exceeded the benchmarks (from Tier II) with reported emissions of a listed pollutant, the pollutant was selected as a high-risk pollutant.

Criteria, Subcriteria, and Endpoints

Health effects

Carcinogenicity

- potency factors
- weight -of- evidence (EPA)
- CERCLA Section 102 hazard ranking

Reproductive and developmental toxicity

- LOEL

Acute lethality

- LD₅₀
- LC₅₀

Systemic effects (other than acute lethality)

- inhalation RfC
- oral RfD
- LOEL (oral, inhalation or dermal)

Exposure

- estimated ambient air concentration (using EPA's Human Exposure Model)
- national emissions data

"Both human and animal studies for each health effects category were examined and data from studies involving inhalation, ingestion, and dermal routes of exposure were considered."

Data Selection Approach

A data hierarchy is specified for toxicity information. Exposure is modelled in the Tier II analysis and TRI data, or other similar data are necessary in the Tier III analysis.

A Classification System for Hazardous Chemical Wastes

References

Crutcher, M.R., & F.L. Parker (1990). A Classification System for Hazardous Chemical Wastes. Superfund 90, Hazardous Materials Control Research Institute, 11th Annual National Conference, 222-225.

Developed for Use by

Those who manage and dispose of hazardous chemical wastes

Purpose

"A simple, quick method of ranking hazardous substances can be used to assist managing the disposal of these substances"

Chemicals Addressed: Six organic compounds and lead

Summary of Method or Algorithm

A hazard potential number which considers toxicity, adsorption potential and degradation potential is determined according to the following equation:

$$\text{HPN} = 10^{6/(\text{K Tox})}$$

HPN = hazard potential number

Tox = maximum concentration level related to an adverse effect (mg/l)

K = adsorption or distribution coefficient (ml/g)

Then the degradation process is considered and the HPN may be determined by the following equation:

$$\text{HPN} = \text{HPN}_o \exp [-(k_b + k_H)t]$$

HPN_o = HPN at time t_o

k_b = biological degradation rate constant (time)⁻¹

k_H = hydrolysis degradation rate constant (time)⁻¹

t = time

The HPN changes over time, allowing substances to change in their relative hazard rankings.

System Summary 8, continued

Criteria, Subcriteria, and Endpoints

Toxicity

- exposure concentrations established by agencies such as EPA or OSHA (based on acute or chronic, human or environmental effects)

Adsorption

- k_d

Degradation

- hydrolysis rate constant
- biodegradation

Data Selection Approach

All of the data are needed for the equations above. Therefore, the system can only be applied on chemicals with this complete data set.

System Summary 9

Revised Hazard Ranking System (HRS)

References

U.S. Environmental Protection Agency. (Dec. 14, 1990). Hazard Ranking System, Final Rule. *Federal Register* 55 (241): 51532 - 51667 (40CFR Part 300).

Developed for Use by: EPA

Purpose

To evaluate the relative potential human health and environmental threat posed by hazardous waste sites for possible inclusion on the National Priority List (NPL).

Chemicals Addressed

A single substance expected to be the most hazardous at a site.

Summary of Method or Algorithm

This system is the principle mechanism for placing sites on the NPL. The HRS pathway scores are based on factors grouped into three categories: the likelihood of release, waste characteristics and targets. The factor category scores are multiplied and then normalized to 100 points to obtain a pathway score [e.g., the groundwater migration pathway score]. The final HRS site score is a combination of scores from four pathways: groundwater migration (S_{gw}), surface water migration (S_{sw}), soil exposure (S_s) and air migration (S_a) using a root-mean-square method:

$$S = (S_{gw}^2 + S_{sw}^2 + S_s^2 + S_a^2/4)^{1/2}$$

Criteria, Subcriteria

Groundwater Migration Pathway

Likelihood of Release

- observed release, or potential to release containment
 - net precipitation
 - depth to aquifer
 - travel time

Waste Characteristics

- toxicity/mobility (human toxicity)*
- hazardous waste quantity

Targets

- nearest well
- population
- resources
- wellhead protection area

Soil Exposure Pathway

Resident Population Threat

Likelihood of Exposure

- observed contamination

Waste Characteristics

- toxicity (human)*
- hazardous waste quantity

Targets

- resident individual
- resident population
- workers
- resources
- terrestrial sensitive environments

Nearby Population Threat

Likelihood of Exposure

- attractiveness/accessibility
- area of contamination

Waste Characteristics

- toxicity*
- hazardous waste quantity

Targets

- population within 1 mile
- nearby individual

System Summary 9, continued

Air Migration Pathway

Likelihood of Release

- observed release, or potential to release
 - gas:
 - gas containment
 - gas source type
 - gas migration potential
 - particulate:
 - particulate containment
 - particulate source type
 - particulate migration potential

Waste Characteristics

- toxicity/mobility (human toxicity)*
- hazardous waste quantity

Targets

- nearest individual
- population
- resources
- sensitive environments

Surface Water Migration Pathway: Overland Flow/Flood Component

Likelihood of Release

- observed release, or potential to release
 - by over-land flow
 - containment
 - runoff
 - distance to surface water
 - by flood
 - containment
 - flood frequency

Drinking Water Threat

Waste Characteristics

- toxicity/persistence*
- hazardous waste quantity

Targets

- nearest intake
- population
- resources

Human Food Chain Threat

Waste Characteristics

- toxicity/persistence/bioaccumulation*
- hazardous waste quantity

System Summary 9, continued

Targets

- food chain individual
- population

Environmental Threat

Waste Characteristics

- ecosystem toxicity/persistence/bioaccumulation*
- hazardous waste quantity

Targets

- sensitive environments

Surface Water Migration Pathway: Groundwater to Surface Water Component

Likelihood of Release

- observed release, or potential to release
 - containment
 - net precipitation
 - depth to aquifer
 - travel time

Drinking Water Threat

Waste Characteristics

- toxicity/mobility/persistence*
- hazardous waste quantity

Targets

- nearest intake
- population
- resources

Human Food Chain Threat

Waste Characteristics

- toxicity/mobility/persistence/bioaccumulation*
- hazardous waste quantity

Targets

- food chain individual
- population

Environmental Threat

Waste Characteristics

- ecosystem toxicity/mobility/persistence/bioaccumulation
- hazardous waste quantity

Targets

- sensitive environments

* For specific endpoints used to characterize toxicity, bioaccumulation and persistence, see Endpoints below

System Summary 9, continued

Endpoints

Bioaccumulation

- BCF
- Log K_{ow}
- water solubility

Persistence

- hydrolysis $t_{1/2}$
- biodegradation $t_{1/2}$
- photolysis $t_{1/2}$
- volatilization $t_{1/2}$
- log k_{ow}

Human Toxicity Factor Values:

Cancer

- slope factor (or 1/6 (ED₁₀))
- WOE rating

Non-cancer, chronic

- reference dose (RfD)

Non-cancer, acute

- oral LD₅₀
- dermal LD₅₀
- dust or mist LC₅₀
- gas or vapor LC₅₀

Ecosystem Toxicity

- EPA chronic Ambient Water Quality Criterion (AWQC)
 - EPA chronic Ambient Aquatic Life Advisory Concentrations (AALAC)
 - EPA acute AWQC
 - Lowest LC₅₀
- (endpoints listed in order of preference)

Data Selection Approach

For human toxicity endpoints, for the substance potentially posing greatest hazard:

- if RfD and slope factor available, use worst of the two
- if either RfD or slope factor available, use available endpoint
- if neither, use acute data
- if no toxicity data available, select another chemical

For ecosystem toxicity endpoints

- The endpoints are listed above in order of preference. If no data are available, select another substance for which data are available.

For persistence

- Select the endpoint which gives the highest value (most persistent)

If there are too many data gaps, another chemical at the site will be selected for scoring.

Criteria to Identify Chemical Candidates for Sunsetting in the Great Lakes Basin

References

Foran, J.A. & B.S. Glenn (1993). *Criteria to Identify Chemical Candidates for Sunsetting in the Great Lakes Basin*. The George Washington University, Environmental Health and Policy Program, Department of Health Care Sciences, Washington, D.C.

Developed for Use by

George Washington University and Pollution Probe of Toronto, Ontario, Canada

Purpose

To develop a mechanism to identify, evaluate and classify chemicals as candidates for Sunsetting in the Great Lakes Basin

Chemicals Addressed

A subset of the (approximately 800) chemicals manufactured, used, or stored in the Great Lakes Basin. The subset consisted of 19 chemicals from EPA's 33/50 list and the US/Canada IJC's Great Lakes critical pollutant list, plus 26 chemicals chosen randomly from the universe of 800 chemicals.

Summary of Method or Algorithm

Chemicals are included on the Sunset candidate list if they:

Score high in any toxicity category and
high in release and production
(excluding pesticides)

or

Score high in any toxicity category and
high in persistence or bioaccumulation
(including pesticides)

System Summary 10, continued

Criteria, Subcriteria, and Endpoints

Bioaccumulation

- bioaccumulation factor (BAF)

Persistence

- $t_{1/2}$ in critical medium (days)

Release and Production Volume

open systems

- amount released to environment (annual)
- production volume (annual)

closed systems

- Production or use volume (annual)

Acute aquatic toxicity

- LC_{50}
- EC_{50}

Chronic aquatic toxicity

- NOAEC

Acute terrestrial and avian (non-mammalian) toxicity

- LD_{50}

Chronic terrestrial and avian (non-mammalian) toxicity

- NOAEL

Acute lethal mammalian toxicity

- LD_{50}

Systemic mammalian toxicity

- severity
- effective dose (mg/kg/day)

Carcinogenicity

- weight -of- evidence
- potency ($1/ED_{10}$)

Reproductive and developmental toxicity

- severity and amount of evidence
- lowest effective dose (mg/kg/day)

Ecological effects;

- evidence of ecological disruption

Data Selection Approach

For the most part, the most conservative data are used in scoring each criteria as high, medium or low. Data must be available for at least one exposure parameter and one toxicity parameter for a chemical to be scored and potentially classified as a Sunset candidate.

Systematic Data Collection and Handling for Priority Setting

References

Gjøvs, N., M. Møller, G.S. Hæggh, & K. Kolset (1989). *Existing Chemicals: Systematic Data Collection and Handling for Priority Setting*. Center for Industrial Research. Nordic Council of Ministers, Copenhagen.

Developed for Use by

General use within the European Communities (EC)

Purpose

General method of sorting and selecting chemicals. "To provide management tools for national work on control and regulations of chemicals".

Chemicals Addressed

Two lists of chemicals consisting of 42 substances in car care products and 189 substances in builders' supplies

Summary of Method or Algorithm

Categorization is based on 3 selection elements-exposure, health effects and environmental effects. Individual elements may be classified as High, Medium or Low. Chemicals are sorted into 3 selection groups:

- selected chemicals
- non-selected chemicals
- standby chemicals

The criteria for combining exposure and effects in order to assign chemicals to the 3 groups depends on the purpose of selection and may be altered by the user. One example is presented in which selected chemicals score High for effects (health or environmental) or a Medium for effects combined with a high in exposure. Non-selected chemicals scored Low for effects or Medium in effects and a Low for exposure. The standby chemicals were those for which relevant data were missing.

System Summary 11, continued

Criteria, Subcriteria, and Endpoints

Exposure

Production and import volume

Physical properties

- boiling point
- flash point
- explosivity

(use pattern and occurrence left to a later review stage)

Health Effects

Acute toxicity

- LD₅₀ oral, rat
- LD₅₀ dermal, rat/rabbit
- LC₅₀ inhalation, rat
- Irritation (y/n)
- Sensitization (y/n)
- General toxicity (y/n)
- Genotoxicity (y/n)
- Carcinogenicity (y/n)
- Reproductive damage / Teratogenicity (y/n)

Environmental Effects

Biodegradability

- BOD₂₈
- BOD₅

Bioaccumulation

- log K_{ow}
- water solubility
- molecular weight

Toxicity, aquatic

- LC₅₀ fish
- LC₅₀ daphnia
- LC₅₀ shrimp
- EC₅₀ algae

Terrestrial (no endpoint specified)

Data Selection Approach

All available data are used to score a chemical for each criteria. An overall score for exposure, health effects and environmental effects is based on the number of criteria scoring a certain way. For example, a chemical receives a rating of "high" for health effects if at least one of the health effects criteria receives a high rating. Therefore, the system works in the absence of data, but the use of estimation methods is encouraged (expert judgment, SARs and QSARs).

Substances and Preparations Dangerous for the Environment

References

Gustafsson, L. & E. Ljung (1990). *Substances and Preparations Dangerous for the Environment: A System for Classification, Labelling and Safety Data Sheets*. Final Report from a Nordic Working Group, Nordic Council of Ministers, Copenhagen. Miljørapport: 1990:10E.

Developed for Use by

Nordic Countries

Purpose

A proposed system for classification, labeling, and safety data sheets for substances and preparations dangerous for the environment. There is already a list of substances "Hazardous to Health".

Chemicals Addressed

Applicable to all chemical products (substances and preparations), including pesticides

Summary of Method or Algorithm

Substances are classified as "dangerous for the environment" if one of the following 4 criteria are met:

1. The substance is very acutely toxic
2. The substance is acutely toxic and bioaccumulating/potentially bioaccumulating
3. The substance is acutely toxic and not readily biodegradable
4. The substance is bioaccumulating/potentially bioaccumulating and not readily biodegradable

These classifications are based on numeric cutoff values for the various endpoints (outlined below).

System Summary 12, continued

Criteria, Subcriteria, and Endpoints

Acute toxicity

- LC/EC₅₀ fish/Daphnia/algae or
- LD₅₀ oral, rat or
- LC₅₀ inhalation, rat

Bioaccumulation

- BCF or
- K_{ow}

Biodegradability

- OECD 28-day test or
- BOD₅
- COD

Coverage criteria

- other immediate or long-term danger not covered by the specific criteria

Data Selection Approach

All readily available data are considered. Substances are considered "dangerous to the environment" if any one of the four conditions previously mentioned are met, based on numeric cutoff values.

Vectorial Approach for Partial Ordering

References

Halfon, E., & M.G. Reggiani (1986). Notes on Ranking Chemicals for Environmental Hazard. *Environ. Sci. Technol.* 20, 1173-1179.

Developed for Use by: General use

Purpose

Method of vectorial (rather than scalar) ranking is presented

Chemicals Addressed

34 selected organic chemicals and a set of 6 chlorobenzenes

Summary of Method or Algorithm

Chemicals are ranked for environment hazard according to test results relevant to their fate and/or toxicity using a vectorial approach for partial ordering. Ranking results are based on set theory and systems analysis and are displayed graphically with Hasse diagrams.

System Summary 13, continued

Criteria, Subcriteria, and Endpoints

The method could apply to any set of criteria. The examples used included:

Bioaccumulation

- bioaccumulation in algae
- bioaccumulation in fish
- bioaccumulation in activated sludge
- percent retention in rats

Degradation

- mineralization rates by activated sludge (% CO₂)
- degradation by photoirradiation (% CO₂)
- percent organic fragments

Toxicity

- fish toxicity
- zooplankton toxicity
- microtox test

Data Selection Approach

Not specified

Application of the Hazard Ranking System to the Prioritization of Organic Compounds Identified at Hazardous Waste Sites

References

Hallstedt, P.A., M.A. Puskar, & S.P. Levine (1986). Application of the Hazard Ranking System to the Prioritization of Organic Compounds Identified at Hazardous Waste Remedial Action Sites. *Hazardous Waste and Hazardous Materials*, 3(2), 221-232.

Developed for Use by: Those involved with hazardous waste site investigative studies, monitoring efforts or analytic method development projects.

Purpose

To analyze organic chemicals at 32 hazardous waste remedial action sites and prioritize them as potential threats to public health and the environment. One possible use would be to narrow the list of target organic compounds analyzed for in site investigations or monitoring efforts.

Chemicals Addressed

113 organic priority pollutants common to hazardous waste sites

Summary of Method or Algorithm

A combined rating factor (CRF) is obtained for each chemical scored (taken from the HRS, EPA, 1990) based on a scoring matrix:

		Persistence			
		0	1	2	3
Toxicity	0	0	0	0	0
	1	3	6	9	12
	2	6	9	12	15
	3	9	12	15	18

Toxicity is based on the Sax rating, persistence is based on an EPA rating scale. The scoring results in a combined rating factor (CRF), which is multiplied by frequency of occurrence to arrive at a total score.

System Summary 14, continued

Criteria, Subcriteria, and Endpoints

Toxicity

- Sax rating

Persistence

- EPA rating scale

Frequency of occurrence (percent)

Data Selection Approach

Data are needed for each of the 3 criteria. It is not specified what is done in the absence of data. All common chemical isomers were grouped together, and for groups of isomers the most conservative toxicity or persistence values were chosen.

Modified Hazard Ranking System (mHRS)

References

Hawley, K.A., & B.A. Napier (1985). *A Ranking System for Hazardous Sites & With Mixed Radioactive and Hazardous Wastes*, Proceedings of the Fifth DOE Environmental Protection Information Meeting, November 6-8, 1984, published April, 1985. CONF-841187 Volume 1. U.S. Department of Energy, Office of Operational Safety, Pacific Northwest Laboratory, Richland, WA.

Developed for Use by: U. S. Department of Energy (DOE)

Purpose: It is a modification of the basic HRS which adds the capability to consider radioactive wastes

Chemicals Addressed: Radionuclides

Summary of Method or Algorithm

Modifications to the HRS were restricted to the waste characteristics section of each exposure route. Scores for radioactive waste characteristics are determined by a power function for compatibility with the existing HRS.

Modified HRS Logic Diagram:

This is done for each of five exposure routes:

- migration through air
- migration through surface water
- migration through groundwater
- exposure by fire or explosion
- direct contact with material at the site

System Summary 15, continued

Criteria, Subcriteria, and Endpoints

Radioactive Waste Characteristics Score, scored for each exposure route

- unit dose factor (rem/pCi/L)
- concentration (pCi/L)

Data Selection Approach

Radioactive wastes may be ranked for cases where the concentrations of the radionuclides are known, or where they may be estimated as a "potential dose."

A Ground Water Pollution Priority System (GWPPS)

References

Hutchinson, W.R., & J.L. Hoffman (1983). *A Ground Water Pollution Priority System* (N.J. Geological Survey Open File, Report No. 83-4). Division of Water Resources, Trenton, NJ.

Developed for Use by: New Jersey Geological Survey

Purpose

To prioritize groundwater pollution sites. "Scores from one site can be compared to scores from other sites to determine which site most threatens human health and the environment through groundwater."

Objectives:

1. Provide a simple rating method
2. Provide a checklist of factors for consideration in order to reduce review time on a groundwater pollution investigation
3. Provide a standardized evaluation system

Summary of Method or Algorithm

There are seven steps for rating the potential hazard at a site:

1. Site identification
2. Compile background information
3. Resolve problems with missing data
4. Assign rating scale levels to indicate the relative severity of a situation
5. Calculate rating factor scores
6. Calculate group subscores
7. Calculate overall score

Occurrences of groundwater contamination are scored from 0 - 100 for degree of severity based on 19 rating factors (RFs). Each rating factor is quantified on a rating scale level of 0,1,2, or 3 based on relative severity. A multiplier is assigned based on the importance of each factor to groundwater contamination.

factor score = rating scale level x multiplier
(relative severity) (importance)

group subscore = $100 \times \frac{\text{sum of factor scores}}{\text{maximum possible sum}}$

overall site score = $100 \times \frac{\text{sum of all factor scores}}{\text{sum of all maximum possible scores}}$

System Summary 16, continued

Criteria, Subcriteria, and Endpoints

Site Characteristics Rating Factors:

- Distance to nearest well
- Distance to nearest surface water
- Background groundwater quality
- Recharge
- Unsaturated zone thickness
- Unsaturated zone permeability
- Saturated aquifer thickness
- Saturated zone permeability
- Hydraulic gradient
- Depth to bedrock
- Population served by endangered aquifer

Waste Characteristics Rating Factors

- Source existence (years)
- Diversity of highly toxic chemicals and known or suspected carcinogens (number of carcinogens, highly toxic chemicals)^a
- Toxicity (Sax levels)^a
- Radioactivity (gross alpha particle activity)
- Persistence (qualitative degree of persistence)^a
- In-site compound mobility (qualitative assessment of mobility)^a
- Hazardous waste quantity (volume)
- Total waste quantity (volume)

^a Critical factors which must be considered for evaluation

Data Selection Approach

The system is intended to be uncomplicated for application by persons of varying expertise. Sources to be used for gathering data for each of the rating factors are specified.

Due to the nature of scoring, missing values may exist for any but the 4 critical factors which are marked above with(^a) The overall site score cannot be evaluated without these.

The Great Lakes Water Quality Agreement Annex, lists 1, 2, and 3

References

International Joint Commission's Binational Objective Development Committee (1989). *The Great Lakes Water Quality Agreement Standard Methods and Annex 1*, Lists of Substances.

Developed for Use by: International Joint Commission

Purpose

"These standard methods are to be used to assist in the identification of substances possessing the potential to impact the Great Lakes System."

Chemicals Addressed

Any chemicals which could adversely impact The Great Lakes System-includes inorganics, organics and pesticides.

Summary of Method or Algorithm

The development of three lists is the first phase in the process for selecting substances for which to develop specific objectives. Based on exposure and effects, these lists categorize actual or potentially hazardous chemicals. Specific criteria are defined to classify substances as present, potentially present, toxic and potentially toxic. The three lists are:

- List 1: Present and Toxic
- List 2: Present and potentially Toxic
- List 3: Potentially present and Toxic

Substances on List 1 will be considered for development of "specific objectives." List 2 substances will be considered for further toxicological testing and may be moved to List 1 if toxic effects are exhibited. Substances on List 3 will be candidates for additional monitoring and may be moved to List 1 if detected within the Great Lakes System.

System Summary 17, continued

Criteria, Subcriteria, and Endpoints

Exposure

Believed to be present

Believed to have the potential of being discharged

Toxic Effects

Acute effects

Aquatic

fresh water cladocerans or midge larvae

- LC₅₀ (48-hr)

- LD₅₀ (48-hr)

- EC₅₀ (48-hr)

other freshwater fish amphibian, aquatic invertebrate

- LC₅₀ (96-hr)

Mammalian

- oral LD₅₀

- inhalation LC₅₀

- dermal LD₅₀

Chronic effects

Aquatic animal

- LOAEC

- fish BCF or BAF

Plants (aquatic or terrestrial)

- IC₅₀ (inhibitory concentration - growth rate)

Mammals

Oral/inhalation toxicity

- LOAEL

Teratogenicity /embryotoxicity

- effective dose

Carcinogenicity

- WOE

Reproductive effects

- effective dose

Mutagenic/genotoxic action

- evidence of specific effects

Non-mammalian, terrestrial organisms (e.g., avian)

- oral LOAEL

Data Selection Approach

Chemicals are selected for inclusion on one of the three lists if certain, specific criteria for exposure and toxicity are met. Any one of several toxicity endpoints may render a classification of "toxic." There is no need to estimate missing data. However, SARs may be used to classify a substance as "potentially toxic".

Rapid Screening of Hazard (RASH) Method

References

Jones, T.D., P.J. Walsh, A.P. Watson, B.A. Owen, L.W. Barnthouse, & D.A. Sanders (1988). Chemical Scoring by a Rapid Screen of Hazard (RASH) Method. *Risk Analysis*, 8(1), 99-118.

Developed for Use by: Not specified

Purpose

A method for deriving relative potency estimates for hazardous substances

Chemicals Addressed

278 chemicals were evaluated

Summary of Method or Algorithm

Relative potency values and permissible environmental concentrations are derived using RTECs and GENE-Tox as the main data sources. Relative potency is determined by comparing the effects of a chemical to the effects from a reference chemical used as a standard of comparison. One of the reference chemicals is taken as the primary standard and secondary standards are scaled to the primary standard.

Compute relative potency by:

- comparing different doses required to induce the same level of effect
- comparing different levels of effect resulting from equal doses
- also by "reasonable" comparisons

System Summary 18, continued

Criteria, Subcriteria, and Endpoints

Only effects are considered, not exposure potential

- chemical toxic potency (no specific endpoints are targeted)

Data Selection Approach

The "interviewing" chemical is compared to a "standard" chemical. These comparisons are based on similar tests. If there are not sufficient matches for comparison, a secondary "standard" may be selected. Missing data are not estimated. For multiple data points, the median potency was chosen as characteristic for a chemical, and the interquartile range used as the estimate of uncertainty.

The Environmental Hazard Ranking System ("Schmallenberg")

References

Klein, W., W. Kördel, A.W. Klein, D. Kuhnen-Clausen, & M. Weiss (1988). Systematic Approach for Environmental Hazard Ranking of New Chemicals. *Chemosphere*, 17, 1445-1462.

Developed for Use by

European Community member states National Competent Authorities

Purpose

A computerized scoring system to assess the environmental hazard of new chemicals with classification into 3 classes: no action / observation / immediate action. Environmental assessment of chemicals under the 6th amendment of the EEC Draft Directive 67/548/EC

Chemicals Addressed

New chemicals entering the market

Summary of Method or Algorithm

Environmental hazard criteria for exposure and effects are scored, and the sum of the scores for all criteria is given as the percentage of the sum of the possible scores. This normalization is performed separately for exposure and effects criteria and for air, water, and soil. Different weights for air, water and soil media are used. For example, acute aquatic toxicity scores in air and soil are ¼ that of contamination of water. A two-dimensional image plot is constructed based on the exposure and effects percentages obtained. These plots are used to assign a chemical to one of three regulatory option categories: no action, observation, or immediate action.

System Summary 19, continued

Criteria, Subcriteria, and Endpoints

Exposure Potential*

quantity in environment

- annual production rate
- use pattern

initial partitioning

- tons/annum for air, water and soil

quantity in compartment (Mackay model, level 1)

- tons/annum for air, water and soil

persistence (biodegradation)

accumulation

- $\log P_{ow}$

Biological Effects*

mutagenicity

subacute mammalian toxicity

- oral, dermal or inhalative 28d. NOEL

acute mammalian toxicity

- oral LD_{50} and dermal LD_{50} or inhalation LC_{50}
- skin irritation
- skin sensitization

acute aquatic toxicity (fish or Daphnia, worst case)

- (lowest) effect concentration
- LC_{50}
- EC_{50}

bioconcentration

- $\log P_{ow}$

* weighted separately for air / soil / water

Data Selection Approach

All acceptable available data are utilized to determine the percentages of the maximal scores to assign in each of the exposure and effects criteria. Data may be estimated using QSARS or by extrapolation from experimental data.

WMS - Scoring System

References

- Könemann, H. & R. Visser (1988). Selection of Chemicals With High Hazard Potential: Part 1: WMS-Scoring System. *Chemosphere*, 17, 1905-1919.
- Timmer, M., H. Könemann, & R. Visser (1988). Selection of Chemicals With High Hazard Potential: Part 2: WMS-Scoring System. *Chemosphere*, 17, 1921-1934.

Developed for Use by

Originally intended for use in the preparation of policy on existing chemicals to be implemented under the Netherlands' Chemical Substances Act. The system may be used by government, industry, or academia for chemical selection.

Purpose

To systematically select a limited numbers of chemicals from a greater number, as needed to set priorities for further investigation and for development of environmental and health protection policies.

Chemicals Addressed

378 chemicals obtained by merging several international and national lists of hazardous chemicals or those with high exposure potential. The system appears to be applicable to nearly all chemicals in commerce.

Summary of Method or Algorithm

The system was developed using the general methodology described in a report by the OECD. The relative hazards of chemicals can be compared by determining F values where:

$$F = E_f / E_x$$

and F = ratio for a given chemical

E_f = exposure above which (unacceptable) effects are observed

E_x = actual exposure of target organisms

Different E_f and E_x values must be derived for different target systems and for the presence of a chemical in various places in the environment respectively. The target systems considered are mammals (including man) and aquatic organisms. For mammals, three types of effects are considered. The four exposure scenarios include:

- contamination of air (exposure via air)
- contamination of soil / water
- contamination of aquatic biota
- in products

There are 10 useful combinations of target systems and exposure scenarios which give 10 endscores that make up the scoring profile. The endscores reflect the difference between the maximum hazard and the scored hazard. The final selection of chemicals will vary with the application.

System Summary 20, continued

Criteria, Subcriteria, and Endpoints

Effects

Mammals

general toxicity (oral, dermal, inhalation):

- NEL
- LD₅₀
- mutagenicity (amount of evidence from short-term tests)
- carcinogenicity (evidence of carcinogenicity hazard and/or animal data)

Aquatic toxicity

- NOEC
- EC₅₀

Exposure

Environmental exposure

- use volume
- percentage release to the environment (by type of use)
- degradation in air (half-life)
- degradation in soil/water (semi-quantitative)
- relative occurrence in air Mackay model, fugacity
- relative occurrence in soil/water Mackay model, fugacity
- bioconcentration (log P, log BCF)

Exposure via products

- use pattern
- exposure frequency
- intensity of exposure

Data Selection Approach

All readily available data are supplied to at least two experts who score the chemicals independently. Significant differences are discussed and minor differences are averaged. The experts may use SARs and QSARS for scoring.

Benchmark Comparison

References

Laskowski, P.A., C.A.I. Goring, P.J. McCall, & R.L. Swann (1982). Principles of Environmental Risk Analysis: Terrestrial Environment. in *Environmental Risk Analysis for Chemicals*, R. Conway (Ed.), pp. 198-240. Van Nostrand Reinhold, New York.

Developed for Use by

(Not specified)

Purpose

"Data interpretation by benchmark comparison is accomplished by comparing a series of fundamental properties of chemicals whose environmental behavior is unknown with the standards whose environmental behavior is known." The benchmark system is used for ranking compounds.

Chemicals Addressed

It was demonstrated on 27 pesticides

Summary of Method or Algorithm

Chemicals are ranked for each of 6 criteria.
These include :

- 1) leaching potential
- 2) leaching index
- 3) volatility potential
- 4) volatility index
- 5) on-site exposure
- 6) off-site exposure

The system does not combine the criteria for an overall score. Toxicity or potential effects are not considered. Therefore, this is not a risk-based chemical ranking system. It is useful, however, to examine the exposure component of the system.

System Summary 21, continued

Criteria, Subcriteria, and Endpoints

Leaching Potential

Relative on-site and off-site exposure based on:

- soil $t^{1/2}$
- vapor pressure
- water solubility
- soil adsorption constant (k_{oc})
- octanol-water partition coefficient (k_{ow})
- volume of material manufactured
- frequency of application
- concentration of chemical introduced

Data Selection Approach

Data are needed for each endpoint in order to calculate a score for each of the six criteria.

Michigan Critical Materials Register (CMR)

References

Michigan Department of Natural Resources (MDNR) (1987). *Critical Materials Register*. (Criteria and Support Documents).

Developed for Use by

Michigan Department of Natural Resources

Purpose

To prepare a "list of chemicals of high environmental concern from a water pollution control perspective which may be used, discharged and/or disposed of in Michigan". Every business within the state must file an annual report or usage/discharge of critical materials.

Chemicals Addressed

"Those with well recognized adverse effects as well as those materials which may be of specific concern in Michigan."

Summary of Method or Algorithm

Chemicals are scored for several criteria. Those chemicals selected for inclusion in the Register score:

- a "5" (the maximum score) in 2 or more criteria
- an additive level of 15 or greater

Chemicals are selected for a detailed scrutiny and identification of disposition if they score:

- a "5" in one criterion and insufficient information in all other criteria
- a combined level of "10 - 15"

System Summary 22, continued

Criteria, Subcriteria, and Endpoints

Acute toxicity - terrestrial animals

- oral LD₅₀
- dermal LD₅₀
- inhalation LC₅₀

Acute toxicity - aquatic

- LC₅₀
- EC₅₀

Carcinogenicity

- weight-of-evidence

Mutagenicity

- weight-of-evidence (includes several endpoints)

Reproductive/developmental toxicity

- weight-of-evidence
- effective dose

Other toxicity - terrestrial animals (sub-chronic, chronic or acute)

- severity
- effective dose

Other toxicity - aquatic organisms (chronic)

- MATC (based on full or partial life cycle tests)

Phytotoxicity

- EC₅₀

Bioaccumulation

- BCF
- BAF
- log k_{ow}

Physical and chemical properties and environmental fate

- flammability: NFPA rating
- reactivity: NFPA rating
- corrosivity: pH
- aesthetics
 - taste / odor
 - appearance
- environmental distribution and fate
 - persistence in soil/water ($t_{1/2}$)
 - hydrolysis (H $t_{1/2}$)
 - evaporation (E $t_{1/2}$)

Data Selection Approach

Due to the nature of the selection process, data gaps may exist. There is a data hierarchy specified for some criteria. Often times, the most conservative of several scores within a criterion is selected or the geometric mean of multiple acceptable test results may be used for scoring (aquatic acute toxicity). Detailed guidelines for scoring are provided.

**Unfinished Business: A Comparative
Assessment of Environmental Problems**

References

Morgenstern, R., D. Clay, G. Emison, R. Hanmer, & M. Williams (1987). *EPA Unfinished Business Report: A Comparative Assessment of Environmental Problems, Volume 1*. U.S. Environmental Protection Agency, Washington, D.C. (EPA/230/2-87/025a)

Developed for Use by: EPA

Purpose

This system was used for ranking problems, or issues, rather than chemicals. The objective was to rank the relative risks associated with major environmental problems to support long-term EPA priority-setting.

Chemicals Addressed

(Not for chemical ranking/scoring)

Summary of Method or Algorithm

Four work groups were established to rank 31 environmental problems according to the following risk types:

- cancer risks
- non-cancer health risks
- ecological effects
- welfare effects

An overall rank including all risk types was not obtained, but rather a ranking of environmental problems within each risk type category. Similar methods for estimating risk were applied across the four areas whenever possible. The ranking relied heavily on professional judgement, with an emphasis on consensus within the work groups.

Criteria, Subcriteria, and Endpoints

Cancer risk

- exposure
- potency (carcinogen assessment group estimates)
- population exposed

Non-cancer risk

- exposure
- potency (ambient concentration / RfD)

Ecological Risk

- geographical extent of exposure
- intensity of exposure
- length of exposure
- frequency of exposure
- other factors
- ecosystem recovery potential

Welfare effects

- soiling and other material damages
- recreation
- natural resource damage
- damages to other public and commercial property
- damage to groundwater supplies
- losses in aesthetics and non-user values

Data Selection Approach

The ranking was performed through a combination of quantitative and qualitative assessment. Professional judgement was used whenever quantitative information was not available.

Chemical Scoring System for Hazard and Exposure Identification

References

O'Bryan, T.R. & R.H. Ross (1988). Chemical Scoring System for Hazard and Exposure Identification. *J. Toxicol. Env. Health, 1*, 119-34.

Developed for Use by

EPA, Office of Toxic Substances (OTS)

Purpose

Provide a mechanism to systematically screen chemicals for additional scientific evaluation. "The purpose of scoring is to identify, from a large number of existing chemicals, those chemicals that may warrant further investigation."

Chemicals Addressed

Compounds of toxicological and environmental interest to the EPA. Approximately 100 CHIPS chemicals (those for which Chemical Hazard Information Profiles have been prepared for the EPA) and 100 petroleum substances.

Summary of Method or Algorithm

The system combines objective guidelines with professional judgement to evaluate chemicals. Chemicals can be scored on eleven parameters for exposure and effects. All or any combination of parameters may be scored, depending on data availability. Scores for each criteria are not combined for an overall score; the entire set of scores are presented in a scoring profile for each chemical and the scoring profiles are presented graphically.

System Summary 24, continued

Criteria, Subcriteria, and Endpoints

Oncogenicity

- amount/type of evidence

Genotoxicity

- amount/type evidence

Developmental toxicity

- amount/type of evidence

Acute lethality (mammalian)

- inhalation LC₅₀
- dermal LD₅₀
- oral and other LD₅₀

Nonlethal acute toxicity (mammalian)

- severity of effects
- effective dose (mg/m³ or mg/kg)

Subchronic/chronic toxicity (mammalian)

- severity of effects
- effective dose (mg/m³ or mg/kg/day)

Aquatic toxicity

- acute LC₅₀ or EC₅₀
- life-cycle or chronic NOEL

Bioconcentration

- BCF
- log P

Chemical production volume

- kg or lbs

Occupational exposure

- number of workers potentially exposed
- probability of workers exposure
- intensity of workers exposure
 - measured concentration
 - vapor pressure

Consumer exposure

- number consumers potentially exposed
- frequency of consumer exposure
- intensity of consumer exposure

Environmental exposure

- pounds released annually

Environmental fate

- ½ life
- transport
- transformation

Data Selection Approach

Chemicals are scored independently by two experts who may use all readily available data and SARs for scoring. Differences in scores of more than one point are resolved. The scoring may be performed on any or all of the criteria, depending on data availability. Scores are not added, weighted or combined.

The Effluent Monitoring Priority Pollutants List (EMPPL)

References

Environment Ontario (1987). *The Effluent Monitoring Priority Pollutants List*. Ontario Ministry of the Environment, Hazardous Contaminants Coordination Branch. ISBN 0-7729-2784-7

Environment Ontario (1988). *The Effluent Monitoring Priority Pollutants List, 1988 Update*. Ontario Ministry of the Environment, Hazardous Contaminants Coordination Branch. ISBN 0-7729-5450-X

Developed for Use by

Ontario Ministry of the Environment

Purpose

To develop a list of chemicals "which have been detected or are potentially present in Ontario municipal and industrial effluents which pose a hazard to the receiving environment." This will provide a basis for "chemical specific monitoring regulations under the MISA program".

Chemicals Addressed

Chemicals detected in effluents or surface water and chemicals not yet detected but which would be of concern if present.

Summary of Method or Algorithm

A chemical is selected for promotion to the EMPPL if it is present or potentially present in Ontario, and if it meets or exceeds any one of a number of "concern levels" in various other parameters (including persistence, bioaccumulation and toxicity). These parameters are scored using the MOE criteria.

Criteria, Subcriteria, and Endpoints

Persistence

- $t_{1/2}$

Bioaccumulation

- BCF
- $\log K_{ow}$

Acute lethality

- oral LD_{50}
- dermal LD_{50}
- inhalation LD_{50}
- aquatic LC_{50}

Chronic/subchronic

Non-mammals

aquatic

- EC_{50}
- MATC
- NOAEL

terrestrial

- subchronic NOEL
- chronic NOEL

plants (aquatic and terrestrial)

- NOAEC
- EC_{50}

Mammals

- oral NOEL
- inhalation NOEL

Mutagenicity/Genotoxicity

- positive results (test system specified)

Teratogenicity

- effective dose (mg/kg/day)

Carcinogenicity

- criteria rely on amount and type of evidence

Data Selection Approach

The data search strategy is in two levels. Both levels utilize both printed and computer-accessed information for every chemical. Sufficient information for scoring each of the adverse effects parameters is obtained. This may not require searches on both levels. The data selection approach is specified for each of the criteria. For example, preference is given to toxicity data based on route, test duration, species, or the most conservative value. For bioconcentration, BCF values are preferred over K_{ow} and the most conservative value for persistence is selected. Data gaps remaining after a level II search are documented. QSARs, SARs, and expert judgement may be used. This system functions in the absence of data.

Coastal Hazardous Waste Site Review

References

Beckvar, N. & L. Harris (1992). *Coastal Hazardous Waste Site Review, September, 1992*. Hazardous Materials Response and Assessment Division, NOAA/ORCA, Seattle, WA.

Developed for Use by

National Ocean and Atmospheric Administration (NOAA)

Purpose

To select sites (on the NPL or proposed for inclusion) for further investigation that could affect natural resources; to determine the potential for injury to the resources evaluate clean-up alternatives; and to carry out restoration actions. This initial assessment is to provide an overall guide to the potential for injury to NOAA trust resources resulting from a site.

Chemicals Addressed

(Not for chemical ranking/scoring)

Summary of Method or Algorithm

The reviews examine:

- 1) site exposure potential (qualitative information)
- 2) NOAA trust habitats and species
- 3) site-related contamination (maximum concentration of contaminants)

Data from each site are screened against standard comparison values, depending on the media. Such standards used are:

- Ambient water quality criteria
- Selected soil averages
- Effective Range-Low (ER-L) values

The primary concern is with chronic effects.

System Summary 26, continued

Criteria, Subcriteria, and Endpoints

Site-specific data

Data Selection Approach

Site-specific, measurable data are needed for comparisons against standard values.

**SRS: Site Ranking System for
Hazardous Chemical and Radioactive Waste**

References

Rechard, R.P., G.F. Wilkinson, & J.D. Schreiber (1991). *User's Manual for SRS88: Site Ranking System for Chemical and Radioactive Waste* (SAND87-2815, UC-721). Sandia National Laboratories, Albuquerque, NM.

Rechard, R.P., M.S.Y. Chu, & S.L. Brown (1988). *SRS: Site Ranking System for Hazardous Chemical and Radioactive Waste* (SAND86-2994, DOE/HWP-26). Sandia National Laboratories, Albuquerque, NM.

Developed for Use by: U.S. Department of Energy

Purpose

To perform a ranking of hazardous waste sites based on relative human health risks and primarily using information that already exists on the sites. (Primarily *site* ranking, with simple chemical ranking as an initial screening step.)

Chemicals Addressed

Major waste components of sites. Minor waste components are initially screened out based on amount, concentration and toxicity.

Summary of Method or Algorithm

The ranking process involves the following steps:

- collect site data
- rank wastes at a site by quantity and toxicity
- describe contaminant release pathways of concern
- evaluate engineered features at a site
- identify target populations for pathways of concern
- score site characteristics based on contaminant migration
(ground-water, surface water, air pathways)
- combine individual scores to obtain a pathway score
- combine pathway scores to obtain a site score
- rank sites relative to other scored sites

The risks posed by contaminant release from hazardous waste sites is determined by:

population x exposure x toxicity

Criteria, Subcriteria, and Endpoints

Target population

- log of population at risk

Chronic toxicity

- unit cancer risk (UCR) for carcinogens and radionuclides
- allowable daily intake (ADI) for noncarcinogens

Groundwater pathway

- mass of hazardous material initially left at site
- effectiveness of engineered barriers
- effectiveness of site features
- chemical decay rate

Surface water pathway

- method of waste placement
- soil cover and hydraulic structures
- time frame of interest
- decay rate at site

Air pathway

- method of waste placement
- time frame of interest
- decay rate at site

Data Selection Approach

Default scores are assigned for missing site data. Best estimates of chemical or site properties are to be used, rather than conservative upper limits.

A Practical Method for Priority Selections and Risk Assessments Among Existing Chemicals

References

Sampaolo, A. & R. Binetti (1986). Elaboration of a Practical Method for Priority Selections and Risk Assessment Among Existing Chemicals. *Reg. Toxicol. & Pharmacol.*, 6, 129-154.

Sampaolo, A. & R. Binetti (1989). Improvement of a Practical Method for Priority Selections and Risk Assessments Among Existing Chemicals. *Reg. Toxicol. & Pharmacol.*, 10, 185-195.

Developed for Use by: General use

Purpose

A system, for different purposes, for assessment and priority selection of existing chemicals. It has been included as the official method in the Italian decree for the implementation of the EC directive 82/501, particularly for calculating the toxicity risk in case of accident.

Chemicals Addressed

Method validated on 80 substances including inorganics, organics and pesticides

Summary of Method or Algorithm

This system may be used for:

- Assessment of intrinsic properties
- Identification of data needs
- Risk assessment
- Priority assessment in selecting chemicals for further study

Depending on the purpose, there are different equations which result in scores for:

- 1) priority for personal direct exposure
- 2) priority for environmental exposure
- 3) risk for personal direct exposure
- 4) risk for environmental exposure
- 5) general risk index
- 6) application to specific effects (emphasis on types of effects)
- 7) adapted formulas for use for EC directive

The equations include additive and/or multiplications parameters, depending on the objective.

System Summary 28, continued

Criteria, Subcriteria, and Endpoints

Physicochemical properties

- molecular weight
- melting point
- boiling point
- relative density
- vapor pressure
- surface tension
- water solubility
- fat solubility
- flammability
- explosive properties
- oxidizing properties

Toxicological properties

Acute toxicity

- oral LD₅₀
- inhalation LC₅₀
- skin LD₅₀
- irritation (skin and/or eye) EEC "guide on classification and labelling"
- sensitization (EEC guide)

Sub-acute, subchronic, chronic toxicity

- no-effect level (oral, inhalation, cutaneously)
- mutagenicity (EEC guide)
- carcinogenicity (EEC guide)
- reproduction/teratogenicity (EEC guide)

Ecotoxicological properties

- acute LC₅₀, fish
- acute EC₅₀, *Daphnia*
- acute oral LD₅₀, birds
- toxicity for higher plants (qualitative phytotoxicity)
- effects on algae

Multiplier parameters

- quantity on market
- plurality of direct exposure
 - personal exposure
 - domestic exposure
 - professional exposure
- environmental spread
- persistence
 - BOD
 - ThOD
- bioconcentration (log P)
- size of risk population

Data Selection Approach

Scoring criteria are provided for both cases where data are available and unavailable. In the absence of data, scores are assigned on the basis of SAR or other properties of the chemical (fat solubility, qualitative information, etc.).

Chemical Ranking for Potential Health and Environmental Impacts

References

Davis, G.A. et al (1994). Chemical Hazard Evaluation for Management Strategies: A Method for Ranking and Scoring Chemicals by Potential Human Health and Environmental Impacts. University of Tennessee (UT), Center for Clean Products and Clean Technologies, Knoxville, TN.

Developed for Use by

University of Tennessee Center for Clean Products and Clean Technologies

Purpose

"To examine the components of chemical ranking and scoring systems, propose a detailed scheme for chemical ranking, and to recommend a set of priority chemicals for safe substitutes analysis"

Chemicals Addressed

The top 99% releases and transfers from 1989 TRI (organics and inorganics) and several high-volume pesticides.

Summary of Method or Algorithm

An unweighted hazard value is obtained for each chemical based on health, environmental and exposure criteria.

The algorithm (not weighted by releases) is:

$$\text{Total Hazard Value} = (\text{Human Health Effects} + \text{Environmental Effects}) \times \text{Exposure Factor}$$

where:

Human Health Effects = $aHV_{OR} + bHV_{INH} + cHV_{CAN} + dHV_{NC}$ and

Environmental Effects = $aHV_{MAM} + eHV_{FA} + fHV_{FC}$

Exposure Factor = $gHV_{BOD} + hHV_{HYD} + iHV_{BCF}$

HV_{OR} = hazard value for acute oral toxicity (human)

HV_{INH} = hazard value for acute inhalation toxicity (human)

HV_{CAN} = hazard value for carcinogenicity (human)

HV_{NC} = hazard value for chronic, noncarcinogenic toxicity (human)

HV_{MAM} = hazard value for acute oral toxicity (other mammalian)

HV_{FA} = hazard value for acute toxicity to fish

HV_{FC} = hazard value for chronic toxicity to fish

HV_{BOD} = hazard value for acute oral toxicity (other mammalian)

HV_{HYD} = hazard value for acute toxicity to fish

HV_{BCF} = hazard value for chronic toxicity to fish

$a \dots i$ = term weighting factors

System Summary 29, continued

A weighted hazard value is obtained based on releases and transfers as reported in the 1989 TRI and pesticide usage data.

The same algorithm above is used, but release weighting factors (RWFs) are applied to the individual hazard values.

The release weighting factors were calculated as follows:

$$\text{RWF}_{a,w,t} = \ln(\text{releases to air, water or total}) - 10$$

The release-weighted hazard values were obtained as follows:

$$\text{wHV}_{\text{OR}} = (\text{HV}_{\text{OR}})(\text{RWF}_w)$$

$$\text{wHV}_{\text{INH}} = (\text{HV}_{\text{INH}})(\text{RWF}_a)$$

$$\text{wHV}_{\text{CAN}} = (\text{HV}_{\text{CAN}})(\text{RWF}_t)$$

$$\text{wHV}_{\text{NC}} = (\text{HV}_{\text{NC}})(\text{RWF}_t)$$

$$\text{wHV}_{\text{MAM}} = (\text{HV}_{\text{MAM}})(\text{RWF}_w)$$

$$\text{wHV}_{\text{FA}} = (\text{HV}_{\text{FA}})(\text{RWF}_w)$$

$$\text{wHV}_{\text{FC}} = (\text{HV}_{\text{FC}})(\text{RWF}_w)$$

where

wHV_x = release-weighted hazard value for term x

RWF_w = water release weighting factor

RWF_a = air release weighting factor

RWF_t = total release weighting factor

A weighted hazard value is obtained based on releases and transfers as reported in the 1989 TRI.

Criteria, Subcriteria, and Endpoints

Health Effects

Acute

- oral LD₅₀
- inhalation LC₅₀

Chronic

carcinogenicity

- EPA WOE
- IARC strength-of-evidence

non-carcinogenic effects

- chronic toxicity (adverse effects other than cancer)
- developmental toxicity
- mutagenicity
- neurotoxicity
- reproductive toxicity

Environmental Effects

Terrestrial effects

- oral LD₅₀ (rodent)

Aquatic effects

- acute LC₅₀ (fish)
- chronic NOEL (fish)

Exposure Parameters

Persistence

- BOD ½ life
- hydrolysis ½ life

Bioaccumulation

- BCF

Release weighting

TRI releases and transfers

Data Selection Approach

One endpoint for each criterion is required, with preference given to data for a particular species or test duration for most health and environmental effects. When multiple, preferred data are available, the most conservative value is selected. Data are needed for every endpoint and may be estimated by QSARs or SARs where appropriate. Some data gaps remain where estimations are not possible. A sensitivity analysis is performed to evaluate the effects of the data gaps.

A Manual for Evaluating Contamination Potential of Surface Impoundments

References

Silka, L.R., & T.L. Swearingen (1978). *A Manual for Evaluating Contamination Potential of Surface Impoundments*. (EPA 570/9-78-003). Environmental Protection Agency Office of Drinking Water, Washington, D.C.

Developed for Use by

EPA

Purpose

"Rate the contamination potential of groundwater from surface impoundments and to develop practices for the evaluation of different surface impoundments "(pits, ponds, lagoons)

It is considered a first-round evaluation

Chemicals Addressed

Not for chemical ranking/scoring

Summary of Method or Algorithm

The system includes two distinct evaluation phases which involve 1) rating groundwater contamination potential and 2) rating the relative magnitude of the hazard potential to users of the groundwater as a source of drinking water. This involves a six-step process as follows:

<u>Step 1</u>	<u>Step 2</u>	<u>Step 3</u>	<u>Step 4</u>
<u>Step 5</u>	<u>Step 6</u>		
rating	rating	rating	overall groundwater
	rating potential		
unsaturated	groundwater	groundwater	contam. potential
	endangerment to		
zone	availability	quality	hazard potential
	water supplies		

System Summary 30, continued

Criteria, Subcriteria, and Endpoints

Rating unsaturated Zone

Earth material category (see below)

Thickness of unsaturated zone

Groundwater availability

Earth material

- unconsolidated rock
- consolidated rock
- permeability

Thickness of saturated zone

Groundwater quality

- total dissolved solids (TDS)(mg/l)

Waste hazard potential

- toxicity (endpoint not specified)
- mobility
- persistence
- volume
- concentration

Overall groundwater contamination potential

steps 1 - 4 summed

Potential endangerment of waste supplies

distance of impoundment to groundwater or surface water source of drinking water.

anticipated flow direction of waste place

Investigators' degree of confidence

Miscellaneous identifiers

site in groundwater recharge area

site in groundwater discharge area

site in flood plain

+ 6 others

Data Selection Approach

"Precise data are not necessary for the application of the SIA evaluation system...It must be remembered that this evaluation system is a first-round approximation and therefore estimates based on the best available information will be used with the expectation that they will provide satisfactory results for first-round evaluations".

The EPS Enviro-Accounting Method

References

Steen, B. & S. Ryding (1992). *The EPS Enviro-Accounting Method, An Application of Environmental Accounting Principles for Evaluation and Valuation of Environmental Impact in Product Design*. Swedish Environmental Research Institute (IVL), Göteborg, Sweden.

Developed for Use by: General use

Purpose

It is designed to be a tool for life cycle impact assessment, to assess environmental impacts in terms of ecological and health consequences. This includes basic assessment of the values of environmental qualities and changes in these values due to human activities.

Chemicals Addressed

(Not for chemical ranking/scoring)

Summary of Method or Algorithm

Values are assigned to impacts on the environment in terms of five "safe-guard subjects" (human health, biodiversity, production, resources & aesthetic values) according to willingness to pay to restore them to normal status. Emissions, use of resources, and other human activities are then valued according to their estimated contribution to the changes in these safeguarded subjects. The information on environmental impacts originates from LCA-based inventory of the materials/process under study.

Impacts are valued on a relative scale in environmental load units (ELU) which correspond to a standard monetary amount (one ELU equals one ECU in OECD countries).

System Summary 31, continued

Criteria, Subcriteria, and Endpoints

- Biological diversity
- Production
- Human health
- Resources
- Aesthetic values

Data Selection Approach

Empirical data are gathered from the most appropriate available sources. Error estimates should accompany results.

Defense Priority Model

References

U.S. Department of Defense (1992). *User's Manual for the Defense Priority Model* (FY 93 version, Interim Draft). Prepared by Earth Technology Corporation and ERM Program Management Company, for U.S. Department of Defense, Office of Deputy Assistant Secretary of Defense. (Environment), Washington, D.C.

Developed for Use by: Department of Defense

Purpose

Following a remedial investigation feasibility study, site specific data are used to score sites for establishing remedial action priorities on DOD installations. "The DPM provides a numerical score which represents the relative potential threat to human health and the environment."

Chemicals Addressed: Not for chemical ranking or scoring

Summary of Method or Algorithm

Separate subscores are obtained for each of 8 combinations of potential transport pathways and potential receptors as shown below:

	Surface water	Groundwater	Air and Soil	
			(VOCs)	(dust)
human receptors	1	3	5	7
ecological receptors	2	4	6	8

Health and ecological hazards are assessed through monitoring, using toxicological benchmarks that 1) rank toxic chemicals according to relative toxicity; and 2) relate concentrations measured at a site to concentration or doses that may be toxic. Scores for confidence level in data quality are included and an overall site score is obtained.

Score aggregation:

"The pathway, hazard and receptor subscores for each pathway-receptor combination are multiplied together and the products of the subscores are normalized." The larger of the two air/soil pathway scores is used. The final score is obtained by the following algorithm:

$$S_f = [5(S_{s,h})^2 + (S_{s,e})^2 + 5(S_{g,h})^2 + (S_{g,e})^2 + 5(S_{a,h})^2 + (S_{a,e})^2]^{1/2} / 4.24$$

S_f = overall site score, $S_{s,h}$, $S_{s,e}$ etc. = scores for surface water - human health, surface water - ecological etc.

System Summary 32, continued

Criteria, Subcriteria, and Endpoints

Pathway Scoring

Surface water pathway

- detected releases
- distance to nearest surface water
- net precipitation
- surface erosion potential
- rainfall intensity
- hydraulic conductivity
- flooding potential
- waste containment effectiveness factor
- waste quantity factor

Groundwater pathway

- detected releases
- distance waste to water site
- permeability of unsaturated zone
- infiltration potential
- geochemical properties of vadose zone
- waste contamination effectiveness factor
- waste quantity factor

Air/Soil volatiles pathway

- detected releases
- average summer soil temperature
- net precipitation
- wind velocity
- soil porosity
- waste containment effectiveness factor
- waste quantity factor

Air/Soil dust pathway

- detected releases
- net precipitation
- wind velocity
- days/yr > 25 mm precipitation
- site activity
- waste containment effectiveness factor
- waste quantity factor

Contaminant hazard scoring (Get a score for each pathway)

Human health hazard

- measured concentrations
- daily intake (water + fish)
- acceptable daily intake (ADI)

Ecological hazard

- measured concentrations
- ecological effects benchmarks
 - aquatic (kg/l)
 - terrestrial (mg/l)

System Summary 32, continued

Receptors Scoring

surface water receptors

human health

- population obtaining drinking water
- water use to nearest surface water
- population within 1/2 mile of site
- distance to nearest installation boundary
- land use (zoning within 2 miles of site)

ecological

- important biota and habitats near site
- "critical" environments near site

groundwater receptors

human health

- groundwater travel time to water wells
- groundwater travel time to surface water as domestic water source
- groundwater use of uppermost aquifer
- population potentially at risk
- population within 1/2 mile of site
- distance to nearest installation boundary

ecological

- groundwater travel time to habitat or natural area
- important biota and habitats near site "critical" environments near site

air/soil receptors

human health

- population within 4 miles radius
- land use
- distance to nearest installation boundary

ecological

- distance to important biota and habitat
- "critical" environments near site

Data Selection Approach

A summary of the data requirements is provided in Appendix A with a list of general data sources that may be used. Methods of estimation for missing data are provided throughout the document.

Hazardous Air Pollutants: Proposed Regulations Governing Constructed, Reconstructed and Modified Major Sources

References

U.S. Environmental Protection Agency. *Hazardous Air Pollutants: Proposed Regulations Governing Constructed, Reconstructed and Modified Major Sources* (40 CFR Part 63).
February 12, 1993 Draft.

Developed for Use by: EPA

Purpose

Guidance for identification of the relative hazard to human health from emissions of air pollutants (listed as HAPS). One important requirement of section 112(5)(1)(A) of the Clean Air Act (as amended in 1990) is that off setting emissions decreases must be considered "more hazardous" than emission increases. This system may be used to characterize pollutant emissions as more or less hazardous.

Chemicals Addressed

Hazardous air pollutants

Summary of Method or Algorithm

The first step involves assigning pollutants to one of four categories listed below and to determine the relative hazard of the categories.

4 categories of HAPs

- Threshold
- Non-threshold (no safety threshold for exposure can be determined)
- "High-concern" from acute or toxic exposure
- "Unrankable" pollutants

Non-threshold and high concern pollutants are considered "more hazardous" than threshold pollutants. The relative ranking of individual pollutants is done within (not between) these 4 categories. This ranking is based primarily on cancer potency and weight of evidence classification for non-threshold pollutants and composite score differences for threshold and high-concern pollutants.

Criteria, Subcriteria, and Endpoints

Non-threshold pollutants (carcinogens within EPA weight-of-evidence class A, B or C or IARC group 1, 2A or 2B)

Rank within category:

- weight-of-evidence (EPA, IARC)
- Dose-response (ED_{10})

Threshold pollutants

Rank within category:

- Reportable quantities (RQ) composite scores
dose (RV_d)
severity of effect (RV_e)
- oral RfD/inhalation RfCs (alternative option)

High concern pollutants

Criteria to be placed in category:

Ranking within category:

- composite (RQ) scores (for chronic toxicity)
potent acute toxicants (level-of-concern, LOC, $< 8 \text{ mg/m}^3$)

Data Selection Approach

The guidance includes a data hierarchy for "non-threshold" pollutants where EPA assessments are preferred over IARC, and for "threshold" pollutants where RQs are preferred over RfDs. "Unrankable" pollutants include those which do not meet the criteria for non-threshold pollutants or "high concern" pollutants and have insufficient chronic toxicity data to be ranked as "threshold pollutants".

Ranking System for 307 (a) List of Priority Pollutants

References

Poston, T.M. & L.A. Prohammer (1985). *A Ranking System for Clean Water Act Section 307 (a) List of Priority Pollutants*. Prepared by Battelle, for U.S. Environmental Protection Agency.

Cornaby, B.W. et. al. (1986). *Results of Implementation of a Chemical Ranking System*. Prepared by Battelle, for U.S. Environmental Protection Agency Criteria and Standards Division, Washington, D.C.

Developed for Use by: EPA

Purpose

An objective, scientifically-based quantitative ranking system for placement of chemicals on the Clean Water Act Section 307 (a) list of priority pollutants.

Chemicals Addressed

157 chemicals from various agency lists. Includes inorganics, organics and pesticides.

Summary of Method or Algorithm

The system is based on a two-tiered approach. Tier I is based on five effect-based scoring factors: aquatic toxicity, mammalian toxicity, human health effects, bioaccumulation and persistence. A total score of 10 or more points would indicate listing after consideration of Tier II for exposure. Chemicals receiving scores between 8 and 12 points should be reviewed further in Tier II. Tier II scores are not added to Tier I scores.

Criteria, Subcriteria, and Endpoints

Tier I:

Aquatic Toxicity

- acute LC₅₀ (96 -h fish, 48 -h macroinvertebrates)
- chronic MATC (fish, *Daphnia*, midge)
- EC₅₀ (algae)

Mammalian Toxicity

- acute oral LD₅₀
- acute dermal LD₅₀
- chronic/sub-chronic LD_{LO}, TD_{LO}

Human Health:

- carcinogenicity (qualitative evidence)
- mutagenicity (qualitative evidence)
- teratogenicity (qualitative evidence)

Bioaccumulation

- BAF (Bioaccumulation Factor)
- BCF
- log P (octanol-water partition coefficient)

Environmental Persistence (in aquatic environment)

- | | |
|--|--|
| 1985 | 1986 |
| <ul style="list-style-type: none"> • environmental half-life • volatilization • K_d value | <ul style="list-style-type: none"> • hydrolysis • vaporization (Henry's constant) • oxidation |

- hydrolysis rate
- adsorption (K_{oc})

Tier II (examines potential for exposure on a national basis)

Exposure

- amount discharged per year
- number of sites of discharge having detectable concentrations
- frequency of detection in ambient waters
- frequency of detection in aquatic sediments
- frequency of detection in industrial or municipal effluents

Data Selection Approach

A data hierarchy exists for some criteria. The resulting score indicates the completeness of the data. Chemicals with sufficient documented hazards may be listed without a complete data set, but a problem exists for chemicals with potentially wide-spread use for which there is little or no toxicity data. Estimation methods such as QSARs are used.

CERCLA Section 102 Reportable Quantity Ranking Process

References

U.S. Environmental Protection Agency (1989). *Technical Background Document to Support Rule Making Pursuant to CERCLA Section 102* (Volume 3) EPA Office of Solid Waste and Emergency Response.

Environmental Monitoring and Services, Inc. (1985). *Technical Background Document to Support Rule Making Pursuant to CERCLA Section 102* (Volumes 1-2). Prepared for U.S. Environmental Protection Agency.

Developed for Use by: EPA

Purpose

To adjust reportable quantities established under CERCLA and the Clean Water Act, in order to:

- reduce the burdens of reporting
- allow EPA to focus on the most serious released
- more effectively protect the public & environment and to make RQs under CWA and CERCLA consistent

Chemicals Addressed

Hazardous substances as defined in CERCLA

Summary of Method or Algorithm

Each hazardous substance is assigned an RQ level of 1, 10, 100, 1000, or 5000 pounds in several categories (aquatic toxicity, mammalian toxicity, ignitibility/reactivity and chronic toxicity/carcinogenicity). The lowest RQ is selected from 6 primary criteria. An increase of 1 RQ level is possible if indicated by secondary criteria (biodegradability, hydrolysis or photolysis).

System Summary 35, continued

Criteria, Subcriteria, and Endpoints

Primary criteria

Aquatic Toxicity

- 96-hr LC₅₀

Mammalian Toxicity

- oral LD₅₀
- dermal LD₅₀

Ignitability

- flash point
- boiling point
- pyrophoric (y/n)

Reactivity

- self-reacting
- reacts with water
- inflames with water

Chronic toxicity ("toxicity due to single, repeated, or continuous exposure from a single release or multiple releases")

- MED (minimum effective dose) for repeated exposures (mg/day, 70 kg man)
- type of effect (qualitative scale) (composite score = MED x effects)

Carcinogenicity

- potency factor (1/ED₁₀)
- EPA WOE

A matrix including both results in assignment of high, medium or low

Secondary criteria

Biodegradability

- standard BOD tests

Hydrolysis

- identified as "subject to hydrolysis" in EPA-440/4-79-029

Photolysis

- identified as "subject to photolysis"

Data Selection Approach

An RQ is assigned for each of 4 categories (aquatic toxicity, mammalian toxicity, chronic toxicity/carcinogenicity and ignitability/reactivity) for which appropriate data are available. SARs may be used to assign an RQ when little data are available. The final RQ is the lowest RQ in all four categories.

The Source Category Ranking System: (SCRS)

References

Radian Corporation. (1990). *The Source Category Ranking System: Development and Methodology*. Prepared for U.S. Environmental Protection Agency Office of Air Quality Planning Standards, Chemicals and Petroleum Branch.

Developed for Use by: EPA, Office of Air Quality Planning Standards

Purpose

To evaluate and prioritize air pollutant source categories for consideration within the regulatory process. It allows users to analyze pollutant hazards on a process of source category basis rather than on a single compound basis.

Chemicals Addressed

Potential air pollutants

Summary of Method or Algorithm

Long-term and short-term health effects and potential exposure are evaluated and scored separately for individual chemicals. First, long-term health effects data are combined with source and exposure data to obtain a long-term score for each chemical. A parallel evaluation is performed for short-term health effects data, combined with source and exposure data, to obtain a short-term score for each chemical. The long-term and short-term scores are then combined for each chemical to calculate a "net score". Net scores for all chemicals within a given source category are combined to yield a "total score". Source categories are then ranked according to their total scores.

Criteria, Subcriteria, and Endpoints

Health effects

- carcinogenicity
- reproductive and developmental toxicity
- acute toxicity
- non-lethal health effects

Exposure

Pollutant concentration

Emissions estimates

- emission rate
- emission type (point, area, fugitive)

Atmospheric dispersion parameters

- pollutant release height
- pollutant release temperature
- pollutant release flow rate
- pollutant release vent diameter

Emission source data

- pollutant identification
- source category
- state/county code

Population exposed

- county code
- county population
- county population density

Estimates of pollutant concentration

Data Selection Approach

Data are needed for each endpoint, but may be estimated, as described. Endpoints for the health effects criteria were not specified.

Sax Toxicity Rating System

References

Sax, N.I. & R.J. Lewis (1989). *Dangerous Properties of Industrial Materials*, volume 1, seventh edition. Van Nostrand Reinhold, New York.

Developed for Use by

Developed for inclusion in the reference cited to be used by the general public. It has subsequently been widely used by site ranking systems such as the original HRS.

Purpose

To rank chemical substances into three categories - low, medium or high based on toxicity and fire, reactive and explosive hazard.

Chemicals Addressed

A large number of industrial chemicals

Summary of Method or Algorithm

Substances are rated according to qualitative and quantitative criteria as follows:

Slight or mild toxicity (1)

- substances which produce changes in the human body which are readily reversible and disappear when exposure ceases
- LD₅₀ between 4,000 and 40,000 mg/kg/day
- LC₅₀ between 500 and 2500 ppm
- combustible

Moderate toxicity (2)

- substances which produce reversible changes in the human body, without causing serious physical or health impairment or threatening life
- LD₅₀ between 400 and 4,000 mg/kg/day
- LC₅₀ between 100-500 ppm
- highly flammable or reactive

High toxicity (3)

- substances which cause irreversible changes in the human body, producing serious physical or health impairment or threatening life
- LD₅₀ < 400 mg/kg/day
- LC₅₀ between 100 and 500 ppm
- explosive, spontaneously flammable or highly reactive

Criteria, Subcriteria, and Endpoints

Toxicity

acute local

- qualitative assessment

acute systemic

- qualitative assessment
- LD₅₀
- LC₅₀

chronic local

- qualitative assessment

chronic systemic

- qualitative assessment

Flammability

- qualitative assessment

Reactivity

- qualitative assessment

Explosivity

- qualitative assessment

Data Selection Approach

Quantitative scoring criteria are provided only for acute toxicity. Therefore, it is not clear exactly how the criteria are combined for an overall assessment. It appears as though all available data are used to assign chemicals to one of the three groups and it is not stated how substances with minimal data are characterized.

**Examination of the Severity of Toxic Effects and Recommendations
of a Systematic Approach to Rank Adverse Effects**

References

Environ Corporation (1986). *Examination of the Severity of Toxic Effects and Recommendation of a Systematic Approach to Rank Adverse Effects*. Prepared for U.S. Environmental Protection Agency, Office of Environmental Criteria and Assessment.

Developed for Use by: EPA

Purpose

To identify issues related to assessing severity, to review pertinent information for understanding how measures of toxic effects reflect impairment of function and to utilize the resulting knowledge (resulting from this study) and understanding of severity (of toxic effects) to develop and analyze a numerical ranking or scoring scheme that might be used as a supplement to other information in evaluating the health significance of a substance in the environment.

Chemicals Addressed

Not specifically intended for chemical ranking/scoring. It may be applied to data for almost any chemical.

Summary of Method or Algorithm

Two algorithms are presented for determining a total severity score as indicated below:

Scheme 1:

Total severity score = (histopathology severity score + histopathology score modifier) x organ system factor

Scheme 2:

Total severity score = (toxicity test endpoint score + toxicity test endpoint modifier)
(x organ system factor)

System Summary 38, continued

Criteria, Subcriteria, and Endpoints

2 Schemes Presented

Scheme 1:

Histopathology severity score (type of histopathologic lesion)

Histopathology severity score modifier

- organ weight change
- biochemical change
- organ system impairment

Organ system factor

based on ranking of organ importance and availability of replacement therapy
includes teratogenesis and fetotoxicity

Scheme 2:

Toxicity test endpoint severity score (based on type of effect)

Toxicity test endpoint severity score modifier

- organ weight change
- histopathological change

Organ system factor

- number of organs or organ systems affected

Data Selection Approach

The system is used to rank the severity of effects and relies on available experimental data only.

Screening Procedures for Chemicals of Importance to the Office of Water

References

U.S. Environmental Protection Agency (1986). *Screening Procedure for Chemicals of Importance to the Office of Water*. EPA Office of Health and Environmental Assessment.

Developed for Use by: EPA Office of Water

Purpose

A simplified approach for screening and categorizing toxic chemicals

Chemicals Addressed

The approach is suggested for use on chemicals that are important to the Office of Water. It was initially tested on 30 chemicals, including inorganics, organics and pesticides.

Summary of Method or Algorithm

The screening procedure first assigns chemicals to one of a number of ranked categories. Criteria are set for "high" exposure and toxicity based on population and route of concern. Categories, not chemicals, are numerically scored, but chemicals may be ranked within a category. There are some suggested approaches for ranking within these categories. The ranked categories are listed below:

Rank Category

1. Chemicals legislatively mandated
2. Chemicals with high exposure and high toxicity
3. Chemicals with high exposure and low/unknown toxicity
4. Chemicals with high toxicity and low/unknown exposure
5. Chemicals with low/unknown exposure and toxicity
6. Chemicals screened out because of fate properties, etc. (includes chemicals with a very short environmental life time, those known to be "non-toxic", or those outside the EPA's jurisdiction, e.g. drugs)

Chemicals are first examined for inclusion in group 1 and group 6. Those not included in either of these groups are reviewed and compared against criteria established for inclusion into the other groups. The criteria differ for each combination of route and population.

Criteria, Subcriteria, and Endpoints

Toxicity

Human

- human carcinogen (definite /probable/possible)
- developmental toxicity

Aquatic

- acute (LC_{50})
- chronic

Exposure

Human

drinking water exposure

- detection in drinking water
- detection in ambient water
- detection in wastewater effluent
- ENDPART prediction

fish ingestion exposure

- detected in fish
- detected in Ambient waters or sediment and $BCF > 1000$
- detected in wastewater effluents and $BCF > 1000$
- ENDPART prediction

Aquatic

- detection in ambient water (sediment /biota)
- detection in wastewater effluents
- ENDPART prediction
- BCF

Data Selection Approach

A score of "high" may be given for human or aquatic toxicity or exposure if one or two of several conditions are met. Therefore, data are not required for every endpoint. QSARs and other prediction models may be used to estimate missing data.

Measuring Air Quality: The New Pollutant Standards Index (PSI)

References

U.S. Environmental Protection Agency (1978). *Measuring Air Quality: The New Pollutants Standards Index*. EPA Office of Policy Analysis.

Developed for Use by

Local and state air pollution control agencies

Purpose

"PSI provides a simple, uniform way to report daily air pollution concentrations, to tell the public about the general health effects associated with these concentrations..."

Chemicals Addressed

Not intended for chemical ranking or scoring

Summary of Method or Algorithm

A subindex is calculated for each of five air pollutants, as described below:

observed concentration / NAAQS = subindex

where NAAQS is the National Ambient Air Quality Standard.

The Pollutant Standards Index (PSI) is equal to the maximum subindex. This may be used for reporting conditions to the public according to the following scale:

<u>PSI</u>	<u>Conditions</u>
0 - 5	"good"
Above 50	"moderate"
Above 100	"unhealthful"
200 - 299	"very unhealthful"
300 +	"hazardous"
500	"significant harm level"

System Summary 40, continued

Criteria, Subcriteria, and Endpoints

Observed concentration of the pollutant
NAAQS

Data Selection Approach

The system can be used whenever the concentration of an air pollutant as well as its NAAQS are known.

Ranking the Relative Hazards of Industrial Discharges to POTWs and Surface Waters

References

Abt. Associates, Inc. (1991). *Ranking the Relative Hazards of Industrial Discharges to POTWs and Surface Waters*. Prepared for U.S. Environmental Protection Agency, Office of Policy Analysis.

Developed for Use by: EPA

Purpose: "To characterize and provide a hazard ranking of TRI releases to Publicly Owned Treatment Works (POTWs) and surface waters"

Chemicals Addressed: TRI Chemicals

Summary of Method or Algorithm

A hazard index is calculated and rankings for facilities, industries, etc. are provided for cancer, chronic and aquatic risk. This is based on the appropriate Reportable Quantity (RQ) for each category and is calculated as follows:

hazard index:

$$H = \sum R_x / RQ_x$$

where

H= Hazard index for set i

R_x = Pounds released of chemical x

RQ_x = Reportable quantity for chemical x

The three hazard values (cancer, chronic and aquatic) are not combined for a composite rank. The ranks for each category are provided separately. Additionally, using rates to reflect partitioning between sludge, air, water and degradation, rankings are provided for the individual pathway within each category (e.g. cancer, chronic, aquatic).

partitioning:

$$p_w = 1 - P_r$$

$$P_r = P_a + P_s + P_d$$

where

P_r = pollutant specific removal percentage

P_w = pollutant specific water partitioning percentage

P_a = pollutant specific air partitioning percentage

P_s = pollutant specific sludge partitioning percentage

P_d = pollutant specific degradation partitioning percentage

System Summary 41, continued

Indices may also be adjusted by a population density factor to account for varying human exposure potential around each POTW.

Criteria, Subcriteria, and Endpoints

Toxicity

Cancer potency

- RQ

Chronic toxicity

- RQ

Aquatic toxicity

- RQ

Exposure

- pounds released
- partitioning percentages

Data Selection Approach

RQs are required for ranking. When these are not available, a chemical may still be listed, but not ranked. The method is used for many types of assessments (i.e. to rank facilities, countries, chemicals, etc.). Rankings are separate for cancer vs. chronic vs. aquatic hazard indices.

Targeting Pollution Prevention Opportunities Using the 1988 Toxics Release Inventory

References

ICF Incorporated (1990). *Targeting Pollution Prevention Opportunities Using the 1988 Toxics Release Inventory*. Prepared for U.S. Environmental Protection Agency Pollution Prevention Office.

Developed for Use by

EPA Pollution Prevention Office

Purpose

To identify "high priority" TRI chemicals on the basis of toxicity and exposure potential for use in targeting pollution prevention opportunities. Once the "high priority" chemicals were identified the top 50 chemicals, facilities, and SIC codes for releases and transfers were identified.

Chemicals Addressed

1988 TRI chemicals

Summary of Method or Algorithm

1. High priority TRI chemicals were identified based on toxicity and exposure potential, selected for specific release or transfer types as well as for total releases. Chemicals were selected based on type of release/transfer:
 - Point source and fugitive air emissions: based on CPF, potential carcinogen RQ, inhalation RfD, TPQ or presence on CAA Amendments List
 - On-site land releases and underground injection: based on oral RfD, potential carcinogen RQ, CPF; chemicals with low leaching or soil mobility excluded
 - Surface water and POTW releases: based on aquatic toxicity RQ, chronic or acute toxicity AWQC; all chemicals selected from on-site land or underground injection also included
 - Off-site transfers to TSDFs: included if selected based on any other release/transfer type
2. An outline of a proposed method for estimating exposure to TRI chemical releases and transfers is also presented.

Criteria, Subcriteria, and Endpoints

Toxicological Potency

Threshold Planning Quantities (TPQs)

Reportable Quantities (RQs)

- acute toxicity
- chronic toxicity
- carcinogenic potential
- aquatic toxicity

Reference Doses (RfDs)

- inhalation
- oral

Cancer potency factors (CPFs)

Aquatic Water Quality Criteria (AWQC)

- acute
- chronic

Presence on CAA Amendments List

Ecological Risk^a

Phytotoxicity

Chemicals toxic to soil invertebrates (y/n)

RQs -aquatic toxicity RQ; chronic toxicity AWQC; acute AWQC

Exposure Potential^f

Potentially exposed population size

- via air
- via groundwater
- via surface water

TRI release and transfer data

Environmental fate (based on TRI risk screening guide, reference #45)

- volatilization
- leaching/soil mobility
- bioconcentration
- biological treatment

degradation

- abiotic degradation in air
- abiotic degradation in water
- biotic degradation in water
- biotic degradation in soil

It appears as though only those criteria for "toxicological potency" were used in selecting the high priority pollutants. The criteria for "ecological risk" and "exposure potential" were merely suggested, but not utilized.

Data Selection Approach

Each type of release/transfer (e.g. fugitive air, off-site transfers, etc.) has its own algorithm for selecting the "high priority" pollutants. Each algorithm contains several criteria. Chemicals meeting any of the criteria are selected as "high priority" chemicals.

Chemical Use Clusters Scoring Methodology

References

U.S. Environmental Protection Agency (1993). *Chemical Use Clusters Scoring Methodology*. EPA Office of Pollution Prevention and Toxics, Chemical Engineering Branch, Washington, D.C.

Developed for Use by

EPA, Office of Pollution Prevention and Toxics Design for the Environment Program

Purpose

To systematically identify and screen chemical concerns, emphasizing pollution prevention and the use of safer substances.

Chemicals Addressed

Over 700 chemicals, based on chemical functional use categories

Summary of Method or Algorithm

The method involves four major steps. First, chemicals are assigned to use clusters. Next, data are gathered on: potential human and ecological exposure; potential human and ecological hazard; pollution prevention potential; and past EPA regulatory interest. Then, individual chemicals are ranked within clusters. Finally, clusters are ranked as a whole into high, medium, or low concern categories. The overall chemical and cluster scores are obtained as follows:

$$\begin{aligned} \text{Overall chemical score} &= \text{Human risk reduction potential} \\ &\quad + \\ &\quad \text{Ecological risk reduction potential} \\ &\quad + \\ &\quad \text{EPA interest score} \\ \text{Overall cluster score} &= \text{Pollution prevention potential cluster score} \\ &\quad + \\ &\quad \text{average chemical score for cluster} \end{aligned}$$

Overall pollution prevention cluster score = the mean of the release reduction potential scores and the higher of either human health risk reduction potential or ecological health risk reduction potential cluster score.

Criteria, Subcriteria, and Endpoints

Potential Exposure

Human exposure

- use volume
- total releases to the environment
- consumer use
- number of potentially exposed workers
- number of use sites (in SIC codes)
- bioaccumulation (log K_{ow})
- persistence (expert judgement or log K_{ow})

Ecological exposure

- use volume
- total releases to the environment
- number of sites
- bioaccumulation (log K_{ow})
- bioconcentration (BCF)
- persistence

Potential hazard

Human hazard

noncarcinogenic effects

- reference dose (RfD)^a
- reference concentration (RfC)^a
- reportable quantity (RQ)^a
- threshold planning quantity (TPQ)^a
- human health water quality criteria (HHWQC)^a
- chronic NOAEL^b
- chronic LOAEL^b
- subchronic NOAEL^b
- subchronic LOAEL^b
- human health structure activity team rank (HHSATR)^c
- chemical category human toxicity estimate (CCHTE)^c
- TSCA §8(e) submission^c

carcinogenic effects

- weight-of-evidence class
- q₁^{*} potency factor^a
- RQ potency factor^a
- structure activity team rank (SATR)^c
- CCHTE^c
- TSCA §8(e) submission^c

Criteria, Subcriteria, and Endpoints, continued:

Ecological hazard

- aquatic water quality criteria ^a
- aquatic toxicity reportable quantities ^a
- QSARs ^b
- ecotoxicity structure activity relationships (SARs) ^c
- chemical category ecotoxicity estimate ^c

Pollution Prevention Potential

- human risk reduction potential (HRRP)
- ecological risk reduction potential (ERRP)
- release reduction potential

Past EPA regulatory Interest

- EPA interest lists (9 lists)

(a) high quality data; (b) medium quality data; (c) low quality data.

Data Selection Approach

Within each category, any one of several endpoints may be used for assessment. Preference is given to data considered to be of high quality, as specified. For the human health hazard potential score, both the carcinogenic and non-carcinogenic effects are scored and the higher of the two is used for chemical scoring. Likewise, when a pool of endpoints are available for other criteria, the highest rank of the highest quality data are assigned.

Screening Methodology for Pollution Prevention Targeting

References

U.S. Environmental Protection Agency Office of Toxic Substances. (Date unknown). *Screening Methodology for Pollution Prevention Targeting*.

Developed for Use by: EPA

Purpose

"To isolate TRI chemicals which have high production, high releases, and high toxicity concerns"

Chemicals Addressed

The top 100 produced TRI chemicals (based on 1988 TRI)

Summary of Method or Algorithm

A relative hazard score may be obtained for each chemical according to the following equation:

$$\text{Hazard score} = (\text{Onc} \times 3) + (\text{RDN} \times 1) + (\text{Chr} \times 2) + (\text{Eco} \times 2)$$

where:

Onc = toxicity score for cancer or oncogenicity

RDN = toxicity score for reproductive, developmental or neurotoxic effects

Chr = toxicity score for chronic toxicity

Eco = toxicity score for ecotoxic effects

Toxicity scores are based on the HERD Structure Activity Team (SAT) matrix indicating relative concern as follows: high=3, mid-high=2, mid = 1

A composite score combines a measure of exposure with the hazard score:

$$\text{Composite score} = \frac{\text{Releases}}{\text{Production}} \times \text{Hazard score}$$

Criteria, Subcriteria, and Endpoints

Toxicity

- cancer weight-of-evidence
- reproductive, developmental, neuro-toxicity
- chronic toxicity
- ecotoxicity

Exposure

- release volume
- production volume

Data Selection Approach

It appears as though missing data become zeros in the calculation of the hazard score. The use of estimation methods is not discussed.

TRI Risk Screening Guide

References

U.S. Environmental Protection Agency (1989). *Toxic Chemical Release Inventory Risk Screening Guide* (Vol. 1). EPA Office of Toxic Substances. EPA 560/2-89-002.

Developed for Use by

"Those individuals who are involved in interpreting and explaining environmental pollution, exposures, and health risks to the general public, especially at the local or sub-state level."

Purpose

To provide a risk screening procedure that:

- is quick and easy to use
- is scientifically supportable
- is consistent with other EPA risk screening procedures
- can be used with readily available input data
- produces an expression of risk compatible with the type and quality of input data

The framework is intended to aid in priority setting for followup on TRI facilities and chemicals within particular geographic areas.

Chemicals Addressed

TRI chemicals

Summary of Method or Algorithm

"The risk screening system is a simplified version of EPA's Hazard Ranking System." Evaluations are performed on a facility- specific basis by filling out 3 work sheets for each environmental medium of concern:

1. site-specific data
2. chemical-specific data,
3. relative risk work sheet

There are up to 3 media of concern: air, surface water or POTW, and land.

After the facility evaluations, risk-based priorities can be set for follow up investigations of facilities, chemicals, and populations of interest.

This provides guidelines, but it leaves many decisions up to the user.

Criteria, Subcriteria, and Endpoints

Toxicological Potency:

- Reportable Quantities (RQs)
- Threshold Planning Qualities (TPQs)
- Cancer potency (unit risk factors)
- Reference Doses (RfDs)
- Aquatic Water Quality Criteria (AWQC) - acute and chronic

Exposure Evaluation:

- Plausible exposure pathway
 - site-specific data
 - location of chemical release
 - characterization of populations of interest
 - media uses
 - geographic distance to populations of interest
 - physical transport characteristics of area
 - chemical-specific data
 - physical transport characteristics: adsorption, bioconcentration, volatilization (all y/n)
 - environmental transformation characteristics (+ET or -ET)
- Potential environmental levels
 - site-specific data
 - geographic distance to populations of interest
 - physical transport characteristics of area
 - chemical-specific data
 - quantity of release
 - physical transport characteristics
 - environmental transformation characteristics
 - rates of release

Data Selection Approach

This document provides guidelines for setting priorities regarding facilities, but many decisions are left to the user. Therefore, the method of handling data are somewhat flexible.

TRI Screening in OTS

References

U.S. Environmental Protection Agency (Date unknown). *TSCA's TRI Chemical Risk Assessment Pre-Screening Methodology*. EPA Office of Toxic Substances

Developed for Use by: EPA

Purpose

"Select chemicals for risk assessment and possible regulation under TSCA"

Chemicals Addressed

TRI chemicals

Summary of Method or Algorithm

The evaluation method includes five major steps as listed below:

1. prescreening: deferral of chemicals from first round of screening
2. hazard ranking: "high, medium, low" toxicity concerns
3. exposure ranking: "high, medium, low" exposure rank in each environmental medium
4. exposure evaluation: rough quantitative estimates of site-specific exposures
5. preliminary risk assessment: integration of hazard and exposure information

In the screening process, hazard and exposure rankings are combined and selected chemicals undergo further review. A few chemicals are selected for a more detailed exposure evaluation and preliminary risk assessment.

System Summary 46, continued

Criteria, Subcriteria, and Endpoints

Prescreening

- reviewed by the Existing Chemicals Assessment Division (ECAD) to screen out chemicals that are already in a more detailed assessment stage under TSCA and chemicals that are not good TSCA candidates.

Hazard Ranking

e.g. CERCLA RQs, RfDs, carcinogenic slope factors (not specified)

Exposure Ranking:

- TRI data
- fate and transport modeling to air and water
- physical/chemical properties

Data Selection Approach

"This system allows the user to create algorithms to sort and rank chemicals using readily available data." The criteria are not specified and the chemical selection process is ambiguous.

Priority Setting of Existing Chemicals

References

Weiss, M., W. Kördel, D. Kuhnen-Clausen, A.W. Lange, & W. Klein (1988). Priority Setting of Existing Chemicals. *Chemosphere*, 17, 1419-1443.

Developed for Use by: European Community (EC)

Purpose

A system "allowing the selection of those chemicals on the European market which require priority assessment." Substances are to be assessed for hazard or risk.

Chemicals Addressed

European Inventory of Existing Commercial Chemical Substances

Summary of Method or Algorithm

Separate priority settings are made for air, soil and water. Weights are assigned to indicate the relative importance of a criterion for the three compartments. Ranks are determined for exposure and for biological effects for each chemical. The two ranks are plotted for each chemical in a 2-dimensional diagram (with exposure as the ordinant and effects as the abscissa). Different areas on the diagram could be defined. Four are suggested:

- high priority: substances with high toxicity and considerable exposure
- intermediate priority: substances in a mid-range
- lowest priority: substances with low toxicity and low quantities
- "Black Box": chemicals are of highest priority due to unacceptable biological properties whenever the release ratio is ≥ 1 ton/annum

Criteria, Subcriteria, and Endpoints

Exposure Criteria

- quantity in compartment (t/a)
- initial partitioning (t/a)
- biodegradation
- photolysis half life (d)
- accumulation (log P_{ow})

Effects Potential

- carcinogenesis/mutagenesis (y/n)
- prolonged toxicity
 - chronic toxicity (2 yrs)
 - oral / dermal or
 - inhalative
 - subchronic/subacute toxicity
 - oral/dermal
 - inhalative
 - prolonged aquatic toxicity (fish, daphnia; worst case)
 - plant growth
 - algae
 - bioaccumulation or log P_{ow} (if no long term toxicity data available)
- teratogenesis/fertility
 - teratogenesis (y/n)
 - fertility, terrestrial (y/n)
 - fertility, aquatic (y/n)
 - fertility, plants (y/n)
- acute toxicity
 - acute toxicity (not aquatic)
 - rat oral
 - rat dermal
 - rat inhalation
 - birds oral
 - earthworm
 - acute aquatic toxicity (fish, daphnia; worst case)
- skin effects
 - skin irritation (severity)
 - skin sensitization (y/n)

Data Selection Approach

All accessible data are taken into account. A minimal data set is required. QSARs may be used to complete data sets. The minimum data set includes production volume, use type (intermediate/processing/end use) and an acute toxicity test. Missing tests should be performed with high priority. Acute aquatic toxicity and mutagenesis data are also essential, but may be estimated by SARs in most cases. Scores are normalized on a percent scale based on the number of available data.

The Multimedia Environmental Pollutant System Assessment System (MEPAS)
(the follow-up to the Remedial Action Priority System)

References

Whelan, G. et al. (1987). *The Remedial Action Priority System (RAPS): Mathematical Formulations*. U.S. Department of Energy, Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, WA.

Droppo, J.G. et al. (1989). *Supplemental Mathematical Formulations: The Multi-Media Environmental Pollutant Assessment System (MEPAS)*. Pacific Northwest Laboratory, Richland, WA.

Streng, D.C., S.R. Peterson, & S. Sager (1989). *Chemical Data Base for the Multimedia Environmental Pollutant Assessment System (MEPAS): Version 1*. U.S. Department of Energy, Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, WA.

Droppo, J.G., Jr. et al. (1989). *Multimedia Environmental Pollutant Assessment System Application Guidance, Volume 2 - Guidelines for Evaluating MEPAS Input Parameters*. Battelle Memorial Institute, Pacific Northwest Laboratory, Richland, WA.

Whelan, G. et al. (1992). Overview of the Multimedia Environmental Pollutant Assessment System (MEPAS). *Hazardous Waste & Hazardous Materials*, 9 (2), 191-208.

Developed for Use by

Pacific Northwest Laboratories which is operated for the U. S. Department of Energy. MEPAS is used by the DOE in its Environmental Restoration Priority System (ERPS).

Purpose

A site-specific assessment for estimations of potential health impacts. It provides a risk-based ranking of priorities.

Chemicals Addressed

Not intended for chemical ranking or scoring. It includes elements for radioactive wastes, hazardous chemical wastes and mixtures of these.

Summary of Method or Algorithm

The process may be divided into six major steps including identifying the contaminant source, developing the data base, analyzing the transport pathways, performing an exposure analysis and hazard assessment, and assessing the results. The data base is developed with site-specific data. The exposure analysis relies on site-specific fate and transport modelling to estimate exposure via inhalation, ingestion, external dosing and dermal contact. The hazard assessment is for human health and includes assessment of carcinogens, non-carcinogens and radionuclides. The model is much more sophisticated and requires more data than this brief summary indicates.

Criteria, Subcriteria, and Endpoints

Exposure

Relies on site-specific fate and transport modelling and requires many data entries for estimating exposure via the following:

- inhalation
- ingestion
- external dose
- dermal contact

Health Effects (chemical toxicity)

carcinogens

- inhalation cancer potency
- ingestion cancer potency

non-carcinogens

- inhalation RfD
- ingestion RfD

Data Selection Approach

Data are necessary to complete the chemical-specific data summaries. If the necessary data are unavailable, equations may be used to define physical-chemical properties where possible. A data hierarchy is specified for the toxicity parameters when preferred data are unavailable. Default values may be assigned for other parameters in the absence of data.

Canadian ARET Scoring Protocol

References

ARET Criteria Sub-Committee (ARET)(1993). ARET Criteria Sub-Committee Report, revision date September 27, 1993.

ARET Committee (ARET) (1994), The ARET Substance Selection Process and Guidelines, January, 1994

Canadian Labor Congress (CLC) (1992). *A Critique of the Ontario Hazard Assessment System*. CLC Environment Bureau, Ottawa, Ontario.

Developed for Use by: The Canadian government

Purpose

"To select and develop criteria for identifying candidate substances which, due to their physicochemical and toxicological characteristics, warrant action via ARET".

Chemicals Addressed

The criteria will first be applied to substances in the Chemical Evaluation Search and Retrieval System (CESARS) database. Of approximately 2000 substances in the database, about 25% had sufficient data for screening.

Summary of Method or Algorithm

The sub-committee relied on the MOEE *Candidate Substances List for Bans or Phase-Outs* (Socha et al., 1992) during the development of the selection criteria. The proposed selection process involves the following steps:

1. Rank chemicals by toxicity
 - uses MOEE scoring criteria; and
 - data for at least 3 toxicity elements are required to obtain a normalized toxicity score (NTS).
There can be as many as 6 toxicity elements included
2. Screen chemicals by toxicity
 - set an NTS cut-off above which the substances are further considered for action.
 - chemicals receiving a maximum score in any toxicity criterion are further considered for action.
3. Score for bioconcentration and persistence
4. Select substances for inclusion on one of four lists according to the following criteria:
 - The chemical passes the toxicity screen; and
 - Priority List 1: bioconcentration and persistence scores of 7 or 10 (with 10 being the maximum score);
 - List 2A: bioconcentration score of 7 or 10 , but a persistence score lower than 7;

- List 2B: bioconcentration score below 7, but a persistence score of 7 or 10;
- List 3: bioconcentration and persistence scores below 7.

Criteria, Subcriteria, and Endpoints

Persistence

- $t_{1/2}$

Bioaccumulation

- BCF
- $\log k_{ow}$

Acute lethality

- oral LD_{50}
- dermal LD_{50}
- inhalation LC_{50}
- aquatic LC_{50}

Chronic/subchronic

non-mammals

aquatic

- EC_{50}
- MATC
- NOAEC

terrestrial

- subchronic NOEL
- chronic NOEL

plants

- % growth reduction (NOEL, EC_{50})

mammals

- oral NOEL
- inhalation NOEL

Teratogenicity

- effective dose (mg/kg/day)

Carcinogenicity

- combines mechanism of action with number of species
- EPA weight-of-evidence classification
- IARC strength-at-evidence classification

Genotoxicity/Mutagenicity (used only if reliable carcinogenicity data are lacking)

- type of effects (*in vitro* or *in vivo*)

Data Selection Approach

Data for at least 3 toxicity elements, bioconcentration and persistence are required. A data hierarchy is specified for most criteria with preference given to a particular endpoint, duration, etc. Substances for which there are insufficient data are set aside for further data search. Questionable and limited data are flagged. When there are multiple preferred data available for a particular criterion, the "worst case" is selected unless it is deemed to be inappropriate for the Canadian environment.

**Risk Assessment Guidance under CERCLA
- for screening chemicals of potential concern**

References

U.S. Environmental Protection Agency (1989). *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A)*. EPA Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002.

Developed for Use by: EPA

Purpose

"To identify chemicals in a particular medium that - based on concentration and toxicity - are most likely to contribute significantly to risks calculated for exposure scenarios involving that medium, so that the risk assessment is focused on the most significant chemicals." This screening process reduces the number of chemicals that are carried through the risk assessment process.

Chemicals Addressed: Chemicals found at Superfund sites

Summary of Method or Algorithm

Each chemical is scored to obtain a risk factor based on its concentration and toxicity according to the following equation:

$$R_{ij} = (C_{ij})(T_{ij})$$

where:

R_{ij} = risk factor for chemical i in medium j;

C_{ij} = concentration of chemical i in medium j;

T_{ij} = toxicity value for chemical i in medium j (i.e. either the slope factor or 1/RfD)

A total chemical score (per medium) is calculated as follows:

$$R_j = R_{1j} + R_{2j} + R_{3j} \dots R_{ij}$$

where:

R_j = total risk factor for medium j; and

$R_{1j} \dots R_{ij}$ = risk factors for chemical 1 through i in medium j.

A separate R_j is calculated for carcinogenic and non-carcinogenic effects. The ratio of the risk factor for each chemical to the total risk factor (i.e. R_{ij}/R_j) is used to approximate each chemical's relative risk in medium j. Chemicals which do not contribute to a specified fraction of the total risk factor for each medium is not considered further in the risk assessment for that medium.

Criteria, Subcriteria, and Endpoints

Toxicity

carcinogenicity

- slope factor (q_1^*)

non-carcinogenic effects

- 1/RfD

Exposure

- maximum detected concentration

Data Selection Approach

When determining the risk factor for each medium, the absolute units must be the same among chemicals in a particular medium, although the actual units do not matter. The maximum detected concentration should be used for exposure assessment. For obtaining toxicity information, a data hierarchy is supplied. EPA's IRIS data base is the preferred source, and other data sources are used only if the necessary information is not contained in IRIS. Chemicals cannot be screened using this process if toxicity values cannot be obtained, and these chemicals should not be eliminated from the risk assessment. If both oral and inhalation toxicity values are available, the most conservative is selected. If only one exposure route is likely, the corresponding toxicity value should be used.

A Proposal for Priority Setting of Existing Chemical Substances (EC System)

References

van de Zandt, D.T.J. and C.J. van Leeuwen (1992). A Proposal for Priority Setting of Existing Chemical Substances. Netherlands Ministry of Housing, Physical Planning and the Environment, Risk Assessment and Environmental Quality Division.

Developed for Use by

The Directorate-General for Environment, Nuclear Safety and Civil Protection of the Commission of the European Communities

Purpose

It was designed to rank chemicals on the basis of exposure and effects potential. It is to be used to set priorities for further investigation and to identify chemical substances which could pose a real risk to humans and the environment.

Chemicals Addressed: 51 High Production Volume Chemicals (HPVCs)

Summary of Method or Algorithm

The system would generate four lists of values: human health exposure and effects and environmental (aquatic) exposure and effects. These would be combined into two lists which would include one list of priority substances based on the human health hazard potential and another for environmental hazard potential. Eventually, these two lists could be combined into one final priority list. Scores are obtained as follows:

Aquatic exposure

aquatic exposure score = $[\log (\text{tonnage} \times \text{use} \times \text{distribution} \times \text{biodegradation} + 2.824)] \times 1.133$

Aquatic effects

$EFS = (-\log EFV_d \times 1.4) + EFS_i$

EFS = aquatic effects score

EFV_d = direct aquatic effects value

EFS_i = indirect aquatic effects value

Aquatic priority score

aquatic priority score = aquatic exposure x aquatic effects

Human exposure

human exposure score = $[\log (\text{tonnage} \times \text{use} \times \text{physico-chemical score}) + 0.903] \times 1.45$

Human effects

The score is the highest assigned in all categories

Human health priority score

human health priority score = exposure score x effects score

System Summary 51, continued

Criteria, Subcriteria, and Endpoints

Aquatic Exposure

- quantity produced and/or imported (tonnage)
- use pattern
- environmental distribution
 - MacKay Level I modelling
- biodegradation

Aquatic Effects

Acute effects (fish, Daphnia, algae)

- LC₅₀
- EC₅₀

Chronic effects (fish, Daphnia, algae)

- NOEC

Bioconcentration

- BCF
- log K_{ow}
- molecular weight

Human Exposure

- quantity produced or imported
- use patterns
- physico-chemical properties
 - boiling point
 - vapor pressure
 - log K_{ow}

Human Health Effects

Carcinogenicity (were unable to obtain a copy of document where criteria were included)

Mutagenicity

- amount/type of evidence

Reproductive toxicity

- amount/type of evidence

Respiratory sensitization

Repeat dose toxicity

Acute toxicity

Irritation

Skin sensitization

Data Selection Approach

HEDSET data submitted by manufacturers and importers are utilized in the scoring. Sometimes, several data may be available in the data set for the same parameter (e.g. acute fish toxicity). For direct aquatic effects the most sensitive species and/or biological endpoint is selected as the decisive test. For human health effects, all high quality available data are considered, but only one of the applicable criteria is needed for scoring. The highest score assigned becomes the overall human health effects score. Default values are assigned for some parameters in the absence of data.