



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

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Subject: Region 9 PRGs Table 2002 Update

From: Stanford J. Smucker, Ph.D.
Regional Toxicologist (SFD-8-B)
Technical Support Team

To: PRGs Table Users

With this cover letter, we announce the update to the Region 9 PRGs table for 2002. The PRGs table contains over 600 preliminary remediation goals (PRGs) for contaminants in soil, air, and tap water. Region 9 PRGs are risk-based concentrations that are intended to assist risk assessors and others in initial screening-level evaluations of environmental measurements.

As their name implies, Region 9 PRGs may also be viewed as preliminary cleanup goals for an individual chemical, but in this context, they are best viewed as dynamic and subject to change because they are generic and based on direct contact exposures which may not address site-specific conditions and/or indirect exposure pathways at sites (See Exhibit 1-1 in "Region 9 PRGs Table Users Guide/Technical Background Document"). Also for planning purposes, these human health based PRGs should always be considered in conjunction with ARAR-based PRGs (e.g. MCLs), ecological benchmarks, and "background" conditions before establishing a final cleanup level for a particular site.

You can find the PRGs 2002 table, InterCalc tables, "Region 9 PRGs Table Users Guide/Technical Background Document", and additional helpful toxicological and risk assessment information at:

<http://www.epa.gov/region09/waste/sfund/prg/> .

We view risk-based PRGs as "evergreen". Ongoing changes to the PRGs reflect continuing improvements in our scientific knowledge base and state-of-the-art approaches to risk assessment. In the new *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (Supplemental SSL Guidance, EPA 2001a), two different soil ingestion rates are assumed for non-construction workers: 100 mg/day is assumed for outdoor workers whereas 50 mg/day is assumed for indoor workers. The default value of 100 mg/day for outdoor workers is also recommended by EPA's Technical Review Workgroup for Lead (TRW), and it reflects increased exposures to soils for outdoor workers relative to their indoor counterparts. For more on this, please see Section 4.1 of the "Region 9 PRGs Table Users Guide/Technical Background Document" or refer to the Supplemental SSL Guidance available at the following website:

<http://www.epa.gov/superfund/resources/soil/index.htm>

Because the Region 9 PRGs are generic and intended for screening sites early in the investigation process (often before site-specific information is available), we have chosen to use the 100 mg/day soil ingestion (i.e. outdoor worker) assumption to calculate industrial soil PRGs. Please note that previous issues of the Region 9 PRGs table assumed 50 mg/day soil ingestion rate for workers. This change in soil ingestion rates is reflected in a somewhat lower (more stringent) industrial soils PRG for many contaminants. The appropriateness of this assumption for a particular site may be evaluated when additional information becomes available regarding site conditions or site development.

In addition to changes in exposure factor assumptions, several chemicals have new or revised toxicity values that results in changes to the PRG calculations. To facilitate the users review, chemicals with new and revised toxicological criteria are presented in bold in the 2002 table and also listed here for convenience: **acetonitrile, benzyl chloride, boron, bromate, 1,3-butadiene, 1-butanol, butylbenzenes, cacodylic acid, cadmium (California State value), chloroform, chloronitrobenzenes, chrysene (California State value), cobalt, 1,2-dibromo-3-chloropropane (California State value), 1,1-dichloroethylene, diethylene glycol ethers, diethylformamide, dinitrobenzenes, di-n-octyl phthalate, diphenyl sulfone, ethylbenzene, HCH, hexachlorocyclopentadiene, kepone, lead (California State value), MTBE, 2-nitroaniline, carcinogenic PAHs, perchlorate, polychlorinated terphenyls, benzo(k)fluoranthene (California State value), propylbenzene, propylene glycol, quinoline, tetrachloroethylene, tetrahydrofuran, thiocyanate, 1,1,1-trichloroethane, trichloroethylene, 2,4,6-trichlorophenol, 1,2,3-trichloropropane, triphenylphosphine oxide, tris(2-chloroethyl) phosphate, vinyl chloride, and xylene.**

Also in this update to the “Region 9 PRGs Table User’s Guide/Technical Background Document”, we have added a brief discussion of special case chemicals for which an alternate approach was applied in the derivation of the Region 9 PRGs (Section 2.3). Increasingly, chemical-specific approaches are being used that do not lend themselves to a single PRG model. Special case chemicals that are discussed include: cadmium, chromium 6, lead, manganese, nitrate/nitrite, thallium, and vinyl chloride.

Finally it should be recognized by all that use the PRGs table that not all PRG values in the table are “created equal”. For some chemicals, a robust data set exists upon which the toxicological criteria are based whereas for others, there may be relatively few studies that form the basis of the PRG calculation. Also, PRGs for some chemicals are based on withdrawn toxicity values or route-extrapolated values. Withdrawn and route-extrapolated numbers are shown in the table because we still need to deal with these contaminants during the long delays before replacement numbers are ready. Please consult with your toxicologist or agency risk assessor to best address potential uncertainties associated with chemical-specific PRGs, especially if the chemical is a risk driver at your site.

As with any risk-based tool, there exists the potential for misuse. We try to highlight potential problems in Section 3.8. However, it should be noted that the use of PRGs at a particular site becomes the responsibility of the user. It is recommended that the user verify the numbers with an agency toxicologist or risk assessor because the toxicity / exposure information in the table may contain errors or default assumptions that need to be refined based on further evaluation. If you find an error please send me a note via email at smucker.stan@epa.gov.

DISCLAIMER

Preliminary remediation goals (PRGs) focus on common exposure pathways and may not consider all exposure pathways encountered at CERCLA / RCRA sites (Exhibit 1-1). PRGs do not consider impact to groundwater or address ecological concerns. The PRG table is specifically not intended as a (1) stand-alone decision-making tool, (2) as a substitute for EPA guidance for preparing baseline risk assessments, (3) a rule to determine if a waste is hazardous under RCRA, or (4) set of final cleanup or action levels to be applied at contaminated sites.

The guidance set out in this document is not final Agency action. It is not intended, nor can it be relied upon to create any rights enforceable by any party in litigation with the United States. EPA officials may decide to follow the guidance provided herein, or act at variance with the guidance, based on an analysis of specific circumstances. The Agency also reserves the right to change this guidance at any time without public notice.

1.0 INTRODUCTION

Region 9 Preliminary Remediation Goals (PRGs) are risk-based tools for evaluating and cleaning up contaminated sites. They are being used to streamline and standardize all stages of the risk decision-making process.

The Region 9 PRG table combines current EPA toxicity values with "standard" exposure factors to estimate contaminant concentrations in environmental media (soil, air, and water) that the agency considers protective of humans (including sensitive groups), over a lifetime. Chemical concentrations above these levels would not automatically designate a site as "dirty" or trigger a response action. However, exceeding a PRG suggests that further evaluation of the potential risks that may be posed by site contaminants is appropriate. Further evaluation may include additional sampling, consideration of ambient levels in the environment, or a reassessment of the assumptions contained in these screening-level estimates (e.g. appropriateness of route-to-route extrapolations, appropriateness of using chronic toxicity values to evaluate childhood exposures, appropriateness of generic exposure factors for a specific site etc.).

The PRG concentrations presented in the table can be used to screen pollutants in environmental media, trigger further investigation, and provide an initial cleanup goal if applicable. When considering PRGs as cleanup goals, residential concentrations should be used for maximum beneficial uses of a property. Industrial concentrations are included in the table as an alternative cleanup goal for soils. **In general, it is recommended that industrial PRGs not be used for screening sites unless they are used in conjunction with residential values.**

Before applying PRGs as screening tools or initial goals, the user of the table should consider whether the exposure pathways and exposure scenarios at the site are fully accounted for in the PRG calculations. Region 9 PRG concentrations are based on direct contact pathways for which generally accepted methods, models, and assumptions have been developed (i.e. ingestion, dermal contact, and inhalation) for specific land-use conditions and do not consider impact to groundwater or ecological receptors (see Developing a Conceptual Site Model below).

**EXHIBIT 1-1
TYPICAL EXPOSURE PATHWAYS BY MEDIUM
FOR RESIDENTIAL AND INDUSTRIAL LAND USES^a**

EXPOSURE PATHWAYS, ASSUMING:		
MEDIUM	RESIDENTIAL LAND USE	INDUSTRIAL LAND USE
Ground Water	<i>Ingestion from drinking</i>	Ingestion from drinking
	<i>Inhalation of volatiles</i>	Inhalation of volatiles
	Dermal absorption from bathing	Dermal absorption
Surface Water	<i>Ingestion from drinking</i>	Ingestion from drinking
	<i>Inhalation of volatiles</i>	Inhalation of volatiles
	Dermal absorption from bathing	Dermal absorption
	Ingestion during swimming	
	Ingestion of contaminated fish	
Soil	<i>Ingestion</i>	<i>Ingestion</i>
	<i>Inhalation of particulates</i>	<i>Inhalation of particulates</i>
	<i>Inhalation of volatiles</i>	<i>Inhalation of volatiles</i>
	Exposure to indoor air from soil gas	Exposure to indoor air from soil gas
	Exposure to ground water contaminated by soil leachate	Exposure to ground water contaminated by soil leachate
	Ingestion via plant, meat, or dairy products	Inhalation of particulates from trucks and heavy equipment
	<i>Dermal absorption</i>	<i>Dermal absorption</i>

Footnote:

^aExposure pathways considered in the PRG calculations are indicated in boldface italics.

2.0 READING THE PRG TABLE

2.1 General Considerations

With the exceptions described below, PRGs are chemical concentrations that correspond to fixed levels of risk (i.e. either a one-in-one million [10^{-6}] cancer risk or a noncarcinogenic hazard quotient of 1) in soil, air, and water. In most cases, where a substance causes both cancer and noncancer (systemic) effects, the 10^{-6} cancer risk will result in a more stringent criteria and consequently this value is presented in the printed copy of the table. PRG concentrations that equate to a 10^{-6} cancer risk are indicated by "ca". PRG concentrations that equate to a hazard quotient of 1 for noncarcinogenic concerns are indicated by "nc".

If the risk-based concentrations are to be used for site screening, it is recommended that both cancer and noncancer-based PRGs be used. Both carcinogenic and noncarcinogenic values may be obtained at the Region 9 PRG homepage at:

<http://www.epa.gov/region09/waste/sfund/prg/>

It has come to my attention that some users have been multiplying the cancer PRG concentrations by 10 or 100 to set "action levels" for triggering remediation or to set less stringent cleanup levels for a specific site after considering non-risk-based factors such as ambient levels, detection limits, or technological feasibility. This risk management practice recognizes that there may be a range of values that may be "acceptable" for carcinogenic risk (EPA's risk management range is one-in-a-million [10^{-6}] to one-in-ten thousand [10^{-4}]). However, this practice could lead one to overlook serious noncancer health threats and it is strongly recommended that the user consult with a toxicologist or regional risk assessor before doing this. For carcinogens, I have indicated by asterisk ("ca*") in the PRG table where the noncancer PRGs would be exceeded if the cancer value that is displayed is multiplied by 100. Two stars ("ca**") indicate that the noncancer values would be exceeded if the cancer PRG were multiplied by 10. There is no range of "acceptable" noncarcinogenic "risk" so that under no circumstances should noncancer PRGs be multiplied by 10 or 100, when setting final cleanup criteria. In the rare case where noncancer PRGs are more stringent than cancer PRGs set at one-in-one-million risk, a similar approach has been applied (e.g. "nc**").

In general, PRG concentrations in the printed table are risk-based but for soil there are two important exceptions: (1) for several volatile chemicals, PRGs are based on the soil saturation equation ("sat") and (2) for relatively less toxic inorganic and semivolatile contaminants, a non-risk based "ceiling limit" concentration is given as 10^{+5} mg/kg ("max"). At the Region 9 PRG website, the risk-based calculations for these same chemicals are also available in the "InterCalc Tables" if the user wants to view the risk-based concentrations prior to the application of "sat" or "max". For more information on why the "sat" value and not a risk-based value is presented for several volatile chemicals in the PRGs table, please see the discussion in Section 4.5.

With respect to applying a "ceiling limit" for chemicals other than volatiles, it is recognized that this is not a universally accepted approach. Some within the agency argue that all values should be risk-based to allow for scaling (for example, if the risk-based PRG is set at a hazard quotient = 1.0, and the user would like to set the hazard quotient to 0.1 to take into account multiple chemicals, then this is as simple as multiplying the risk-based PRG by 1/10th). If scaling is necessary, PRG users can do

this simply by referring to the “InterCalc Tables” at our website where risk-based soil concentrations are presented for all chemicals (see soil calculations, “combined” pathways column).

In spite of the fact that applying a ceiling limit is not a universally accepted approach, we have opted to continue applying a “max” soil concentration to the PRGs table for the following reasons:

- Risk-based PRGs for some chemicals in soil exceed unity (>1,000,000 mg/kg) which is not possible.
- The ceiling limit of 10^{+5} mg/kg is equivalent to a chemical representing 10% by weight of the soil sample. At this contaminant concentration (and higher), the assumptions for soil contact may be violated (for example, soil adherence and windborne dispersion assumptions) due to the presence of the foreign substance itself.
- PRGs currently do not address short-term exposures (e.g. pica children and construction workers). Although extremely high soil PRGs are likely to represent relatively non-toxic chemicals, such high values may not be justified if in fact more toxicological data were available for evaluating short-term and/or acute exposures.

In addition to Region 9 PRG values, the PRGs table also includes California EPA PRGs (“CAL-Modified PRGs”) for specific chemicals where CAL-EPA screening values may be “significantly” more restrictive than the federal values (see Section 2.4) and EPA OSWER soil screening levels (SSLs) for protection of groundwater (see Section 2.5).

2.2 Toxicity Values

Hierarchy of Toxicity Values

EPA toxicity values, known as noncarcinogenic reference doses (RfD) and carcinogenic slope factors (SF) were obtained from IRIS, NCEA through September 2002, and HEAST (1997). The priority among sources of toxicological constants in order of preference is as follows: (1) IRIS (indicated by “i”), (2) NCEA (“n”), (3) HEAST (“h”), (4) withdrawn from IRIS or HEAST and under review (“x”) or obtained from other EPA documents (“o”). This hierarchy is subject to change once the HEAST tables are updated.

Inhalation Conversion Factors

As of January 1991, IRIS and NCEA databases no longer present RfDs or SFs for the inhalation route. These criteria have been replaced with reference concentrations (RfC) for noncarcinogenic effects and unit risk factors (URF) for carcinogenic effects. However, for purposes of estimating risk and calculating risk-based concentrations, inhalation reference doses (RfDi) and inhalation slope factors (SF_i) are preferred. This is not a problem for most chemicals because the inhalation toxicity criteria are easily converted. To calculate an RfDi from an RfC, the following equation and assumptions may be used for most chemicals:

$$\text{RfDi} \frac{\text{mg}}{(\text{kg} \cdot \text{day})} = \text{RfC} (\text{mg} / \text{m}^3) \times \frac{20\text{m}^3}{\text{day}} \times \frac{1}{70\text{kg}}$$

Likewise, to calculate an SF_i from an inhalation URF, the following equation and assumptions may be used:

$$SF_i \frac{(\text{kg} \cdot \text{day})}{(\text{mg})} = \text{URF} (\text{m}^3 / \text{ug}) \times \frac{\text{day}}{20\text{m}^3} \times 70\text{kg} \times \frac{10^3 \text{ ug}}{\text{mg}}$$

Substances with New or Withdrawn Toxicity Values

To help users rapidly identify substances with new or revised toxicity values, these chemicals are listed in boldface type in the PRGs table. This issue of the table contains new or revised toxicity values for: **acetonitrile, benzyl chloride, boron, bromate, 1,3-butadiene, 1-butanol, butylbenzenes, cacodylic acid, cadmium (California State value), chloroform, chloronitrobenzenes, chrysene (California State value), cobalt, 1,2-dibromo-3-chloropropane (California State value), 1,1-dichloroethylene, diethylene glycol ethers, diethylformamide, dinitrobenzenes, di-n-octyl phthalate, diphenyl sulfone, ethylbenzene, HCH, hexachlorocyclopentadiene, kepone, lead (California State value), MTBE, 2-nitroaniline, carcinogenic PAHs, perchlorate, polychlorinated terphenyls, benzo(k)fluoranthene (California State value), propylbenzene, propylene glycol, quinoline, tetrachloroethylene, tetrahydrofuran, thiocyanate, 1,1,1-trichloroethane, trichloroethylene, 2,4,6-trichlorophenol, 1,2,3-trichloropropane, triphenylphosphine oxide, tris(2-chloroethyl) phosphate, vinyl chloride, and xylene.**

Chemicals that have been delisted because they are outdated, undocumented, or derived from a data base other than IRIS, HEAST or NCEA include: acifluorfen, 4-bromophenyl phenyl ether, chloroacetaldehyde, 2-chloroethyl vinyl ether, hexachlorodibenzo-p-dioxin mixture (HxCDD), maneb, methyl chlorocarbonate, nitrapyrin, nitric oxide, and 4-nitrophenol.

Route-to-Route Methods

Route-to-route extrapolations ("r") were frequently used when there were no toxicity values available for a given route of exposure. Oral cancer slope factors ("SFo") and reference doses ("RfDo") were used for both oral and inhaled exposures for organic compounds lacking inhalation values. Inhalation slope factors ("SF_i") and inhalation reference doses ("RfDi") were used for both inhaled and oral exposures for organic compounds lacking oral values. Route extrapolations were not performed for inorganics due to portal of entry effects and known differences in absorption efficiency for the two routes of exposure.

An additional route extrapolation is the use of oral toxicity values for evaluating dermal exposures. For many chemicals, a scientifically defensible data base does not exist for making an adjustment to the oral slope factor/RfD to estimate a dermal toxicity value. Based on the current guidance (USEPA 2001b), the only chemical for which an adjustment is recommended is cadmium. An oral absorption efficiency of 5% is assumed for cadmium which leads to an estimated dermal reference dose (RfDd) of 2.5E-05 that was used in the soil PRG calculations for cadmium.

Although route-to-route methods may be a useful screening procedure, the appropriateness of these default assumptions for specific contaminants should be verified by a toxicologist or regional risk assessor. Please note that whenever route-extrapolated values are used to calculate risk-based PRGs, additional uncertainties are introduced in the calculation.

2.3 Region 9 PRGs Derived with Special Considerations

Most of the Region 9 PRGs are readily derived by referring to Equations 4-1 thru 4-8 contained in this “User’s Guide/Technical Background Document” to the Region 9 PRGs. However, there are some chemicals for which the standard equations do not apply and/or adjustments to the toxicity values are recommended. These special case chemicals are discussed below.

Cadmium The PRGs for Cadmium are based on the oral RfD for water which is slightly more conservative (by a factor of 2) than the RfD for food. Because the PRGs are considered screening values, we elected to use the more conservative RfD for cadmium. However, reasonable arguments could be made for applying an RfD for food (instead of the oral RfD for water) for some media such as soils.

The water RfD for cadmium assumes a 5% oral absorption factor. The assumption of an oral absorption efficiency of 5% for Cadmium leads to an estimated dermal RfD of 2.5E-05. The PRG calculations incorporate these adjustments per recent guidance (USEPA 2001b).

Chromium 6 For Chromium 6 (Cr6), IRIS shows an air unit risk of 1.2E-2 per (ug/cu.m) or expressed as an inhalation cancer slope factor (adjusting for inhalation/body weight) of 42 (mg/kg-day)⁻¹. However, the supporting documentation in the IRIS file states that these toxicity values are based on an assumed 1:6 ratio of Cr6:Cr3. Because of this assumption, we in Region 9 prefer to present PRGs based on these cancer toxicity values as “total chromium” numbers.

In the PRG tables, we also include a Cr6 specific value (assuming 100% Cr6) that is derived by multiplying the “total chromium” value by 7, yielding a cancer potency factor of 290 (mg/kg-day)⁻¹. This is considered to be an overly conservative assumption by some within the Agency. However, this calculation is also consistent with the State of California's interpretation of the Mancuso study that forms the basis of Cr6's toxicity values.

If you are working on a project outside of California (and outside of Region 9), you may want to contact the appropriate regulatory officials to determine what their position is on this issue. As mentioned, Region 9 also includes PRGs for “total chromium” which is based on the same ratio (1:6 ratio Cr6:Cr3) that forms the basis of the cancer slope factor of 42 (mg/kg-day)⁻¹ presented in IRIS.

Lead Residential PRGs for Lead (Region 9 EPA and California EPA) are derived based on pharmacokinetic models. Both EPA’s Integrated Exposure Uptake Biokinetic (IEUBK) Model and California’s LeadSpread model are designed to predict the probable blood lead concentrations for children between six months and seven years of age who have been exposed to lead through various sources (air, water, soil, dust, diet and *in utero* contributions from the mother). Run in the reverse, these models also allow the user to calculate lead PRGs that are considered “acceptable” by EPA or the State of California.

The California LeadSpread model can also estimate PRGs for non-residential exposures (e.g. worker) whereas EPA uses a second Adult Lead Model to estimate PRGs for an industrial setting.

For more information on EPA’s Lead models used to estimate residential and industrial PRGs, please refer to the following website:

<http://www.epa.gov/oerrpage/superfund/programs/lead/>

For more information on California's LeadSpread Model and Cal-Modified PRGs for lead, please go to:

<http://www.dtsc.ca.gov/ScienceTechnology/ledspred.html>

Manganese The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. The author of the IRIS assessment for manganese recommends that the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g. drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. The explanatory text in IRIS further recommends using a modifying factor of 3 when calculating risks associated with non-food sources due to a number of uncertainties that are discussed in the IRIS file for manganese, leading to a RfD of 0.024 mg/kg-day. This modified RfD is applied in the derivation of the Region 9 PRGs for soil and water. For more information regarding the Manganese RfD, you may want to contact Dr. Bob Benson at (303) 312-7070.

Nitrates/Nitrites Tap water PRGs for Nitrates/Nitrites are based on the MCL as there is no available RfD for these compounds. For more information, please see IRIS at:

<http://www.epa.gov/iriswebp/iris/index.html>

Thallium IRIS has many values for the different salts of thallium. However, our analytical data packages typically report "thallium". Therefore, as a practical matter it makes more sense to report a PRG for plain thallium. We have done this by making the adjustment contained in the IRIS file for thallium sulfate based on the molecular weight of the thallium in the thallium salt. The adjusted oral RfD for plain thallium is 6.6 E-05 mg/kg-day which we use to calculate a thallium PRG.

Vinyl Chloride In EPA's recent reassessment of vinyl chloride toxicity, IRIS presents two cancer slope factors for vinyl chloride (VC): one that is intended to be applied towards evaluating adult risks and a second more protective slope factor that takes into account the unique susceptibility of developing infants and young children. For residential PRGs, the Region 9 PRGs table applies the more conservative cancer potency factor that addresses exposures to both children and adults whereas for the industrial soils PRG, the adult only cancer slope factor is applied.

Because of the age-dependent vulnerability associated with vinyl chloride exposures, and due to the method that is applied in deriving the cancer slope factor for VC, an assumption of a 70 year exposure over the lifetime is assumed, consistent with the way that the toxicity value for VC was derived. Therefore, instead of the usual exposure assumption of 6 years as a child and 24 years as an adult that is assumed for carcinogenic substances, we have revised the exposure assumption for VC to 6 years as a child and 64 years as adult. Since most of the cancer risk is associated with the first 30 years of exposure to VC, there is actually little difference between a 30 year exposure assumption (typically assumed for Superfund risk assessments) and the 70 year exposure assumption that is assumed in calculating the PRG for VC.

2.4 "Cal-Modified PRGs"

When EPA Region 9 first came out with a Draft of the PRGs table in 1992, there was concern expressed by California EPA's Department of Toxic Substances and Control (DTSC) that for some chemicals the risk-based concentrations calculated using Cal-EPA toxicity values were "significantly" more protective than the risk-based PRGs calculated by Region 9. At an interagency meeting

comprised of mostly toxicologists, it was agreed that PRG values are at best order-of-magnitude estimates, so that if we assume a logarithmic scale, then a difference greater than 3.3 (½ log above or below) would be considered a significant difference. Therefore, for individual chemicals where California PRG values are significantly more protective than Region 9 EPA PRGs, Cal-Modified PRGs are included in the Region 9 PRGs table. For more information on Cal-Modified PRGs, the reader may want to contact Dr. Michael Wade in Cal-EPA's Department of Toxic Substances (DTSC) at (916) 255-6653.

Please note that in the State of California, Cal-Modified PRGs should be used as screening levels for contaminated sites because they are more stringent than the Federal numbers.

2.5 Soil Screening Levels

Generic, soil screening levels (SSLs) for the protection of groundwater have been included in the PRG table for 100 of the most common contaminants at Superfund sites. Generic SSLs are derived using default values in standardized equations presented in EPA OSWER's *Soil Screening Guidance* series, available on the web at <http://www.epa.gov/superfund/resources/soil/index.htm>.

The SSLs were developed using a default dilution-attenuation factor (DAF) of 20 to account for natural processes that reduce contaminant concentrations in the subsurface. Also included are generic SSLs that assume no dilution or attenuation between the source and the receptor well (i.e., a DAF of 1). These values can be used at sites where little or no dilution or attenuation of soil leachate concentrations is expected at a site (e.g., sites with shallow water tables, fractured media, karst topography, or source size greater than 30 acres).

In general, if an SSL is not exceeded for the migration to groundwater pathway, the user may eliminate this pathway from further investigation.

It should be noted that in the State of California, the California Regional Water Quality Control Board has derived "California SSLs" for a number of pathways including migration to groundwater. These are not included in the Region 9 PRGs table, but may be accessed at the following website:

<http://www.swrcb.ca.gov/rwqcb2/rbsl.htm>

Or, for more information on the "California SSLs", please contact Dr Roger Brewer at: (510) 622-2374.

2.6 Miscellaneous

Volatile organic compounds (VOCs) are indicated by "1" in the VOC column of the table and in general, are defined as those chemicals having a Henry's Law constant greater than 10^{-5} (atm-m³/mol) and a molecular weight less than 200 g/mole). Three borderline chemicals (dibromochloromethane, 1,2-dibromochloropropane, and pyrene) which do not strictly meet these criteria of volatility have also been included based upon discussions with other state and federal agencies and after a consideration of vapor pressure characteristics etc. Volatile organic chemicals are evaluated for potential volatilization from soil/water to air using volatilization factors (see Section 4.1).

Chemical-specific dermal absorption values for contaminants in soil and dust are presented for arsenic, cadmium, chlordane, 2,4-D, DDT, lindane, TCDD, PAHs, PCBs, and pentachlorophenols as recommended in the “Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim Guidance” (USEPA 2001b). Otherwise, default skin absorption fractions are assumed to be 0.10 for nonvolatile organics. Please note that previous defaults of 0.01 and 0.10 for inorganics and VOCs respectively, have been withdrawn per new guidance.

3.0 USING THE PRG TABLE

The decision to use PRGs at a site will be driven by the potential benefits of having generic risk-based concentrations in the absence of site-specific risk assessments. The original intended use of PRGs was to provide initial cleanup goals for individual chemicals given specific medium and land-use combinations (see RAGS Part B, 1991), however risk-based concentrations have several applications. They can also be used for:

- Setting health-based detection limits for chemicals of potential concern
- Screening sites to determine whether further evaluation is appropriate
- Calculating cumulative risks associated with multiple contaminants

A few basic procedures are recommended for using PRGs properly. These are briefly described below. Potential problems with the use of PRGs are also identified.

3.1 Developing a Conceptual Site Model

The primary condition for use of PRGs is that exposure pathways of concern and conditions at the site match those taken into account by the PRG framework. Thus, it is always necessary to develop a conceptual site model (CSM) to identify likely contaminant source areas, exposure pathways, and potential receptors. This information can be used to determine the applicability of PRGs at the site and the need for additional information. For those pathways not covered by PRGs, a risk assessment specific to these additional pathways may be necessary. Nonetheless, the PRG lookup values will still be useful in such situations for focusing further investigative efforts on the exposure pathways not addressed.

To develop a site-specific CSM, perform an extensive records search and compile existing data (e.g. available site sampling data, historical records, aerial photographs, and hydrogeologic information). Once this information is obtained, CSM worksheets such as those provided in ASTM's *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (1995) can be used to tailor the generic worksheet model to a site-specific CSM. The final CSM diagram represents linkages among contaminant sources, release mechanisms, exposure pathways and routes and receptors. It summarizes our understanding of the contamination problem.

As a final check, the CSM should answer the following questions:

- Are there potential ecological concerns?
- Is there potential for land use other than those covered by the PRGs (that is, residential and industrial)?

- Are there other likely human exposure pathways that were not considered in development of the PRGs (e.g. impact to groundwater, local fish consumption, raising beef, dairy, or other livestock)?
- Are there unusual site conditions (e.g. large areas of contamination, high fugitive dust levels, potential for indoor air contamination)?

If any of these four conditions exist, the PRG may need to be adjusted to reflect this new information. Suggested websites for the evaluation of pathways not currently addressed by Region 9 PRG's are presented in Exhibit 3-1.

**EXHIBIT 3-1
SUGGESTED WEBSITES FOR EVALUATING EXPOSURE
PATHWAYS NOT CURRENTLY ADDRESSED BY REGION 9 PRGs**

EXPOSURE PATHWAY	WEBSITE
Migration of contaminants to an underlying potable aquifer	EPA Soil Screening Guidance: http://www.epa.gov/superfund/resources/soil/index.htm California Water Board Guidance: http://www.swrcb.ca.gov/rwqcb2/rbsl.htm
Ingestion via plant uptake	EPA Soil Screening Guidance: http://www.epa.gov/superfund/resources/soil/index.htm EPA Fertilizer Risk Assessment: http://www.epa.gov/epaoswer/hazwaste/recycle/fertiliz/risk/
Ingestion via meat, dairy products, human milk	EPA Protocol for Combustion Facilities: http://www.epa.gov/epaoswer/hazwaste/combust/riskvol.htm#volume1 California "Hot Spots" Risk Guidelines: http://www.oehha.ca.gov/air/hot_spots/HRSguide.html
Inhalation of volatiles that have migrated into basements or other enclosed spaces.	EPA's Version of Johnson & Ettinger Model: http://www.epa.gov/oerrpage/superfund/programs/risk/airmodel/johnson_ettinger.htm
Ecological pathways	EPA Ecological Soil Screening Guidance: http://www.epa.gov/superfund/programs/risk/ecorisk/ecossl.htm NOAA Sediment Screening Table: http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html

3.2 Background Levels Evaluation

A necessary step in determining the applicability of Region 9 risk-based PRGs is the consideration of background contaminant concentrations. There is new EPA guidance on determining background at sites. *Guidance for Characterizing Background Chemicals in Soil at Superfund Sites* (USEPA 2001c) is available on the web at: <http://www.epa.gov/superfund/programs/risk/background.pdf>.

EPA may be concerned with two types of background at sites: naturally occurring and anthropogenic. Natural background is usually limited to metals whereas anthropogenic (i.e. human-made) “background” includes both organic and inorganic contaminants. Before embarking on an extensive sampling and analysis program to determine local background concentrations in the area, one should first compile existing data on the subject. Far too often there is pertinent information in the literature that gets ignored, resulting in needless expenditures of time and money.

Generally EPA does not clean up below natural background. In some cases, the predictive risk-based models generate PRG levels that lie within or even below typical background. If natural background concentrations are higher than the risk-based PRGs, an adjustment of the PRG is probably needed. Exhibit 3-2 presents summary statistics for selected elements in soils that have background levels that may exceed risk-based PRGs. An illustrative example of this is naturally occurring arsenic in soils which frequently is higher than the risk-based concentration set at a one-in-one-million cancer risk (the PRG for residential soils is 0.39 mg/kg). After considering background concentrations in a local area, EPA Region 9 has at times used the non-cancer PRG (22 mg/kg) to evaluate sites recognizing that this value tends to be above background levels yet still falls within the range of soil concentrations (0.39-39 mg/kg) that equates to EPA’s “acceptable” cancer risk range of 10E-6 to 10E-4.

Where anthropogenic “background” levels exceed PRGs and EPA has determined that a response action is necessary and feasible, EPA's goal will be to develop a comprehensive response to the widespread contamination. This will often require coordination with different authorities that have jurisdiction over the sources of contamination in the area.

**EXHIBIT 3-2
BACKGROUND CONCENTRATIONS OF SELECTED ELEMENTS IN SOILS**

TRACE ELEMENT	U.S. STUDY DATA ¹			CALIFORNIA DATA ²		
	Range	GeoMean	ArMean	Range	GeoMean	ArMean
Arsenic	<.1-97	5.2 mg/kg	7.2 mg/kg	0.59-11	2.75 mg/kg	3.54 mg/kg
Beryllium	<1-15	0.63 “	0.92 “	0.10-2.7	1.14 “	1.28 “
Cadmium	<1-10	--	<1	0.05-1.7	0.26	0.36
Chromium	1-2000	37	54	23-1579	76.25	122.08
Nickel	<5-700	13	19	9.0-509	35.75	56.60

¹Shacklette and Hansford, “Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States”, USGS Professional Paper 1270, 1984.

²Bradford et. al, “Background Concentrations of Trace and Major Elements in California Soils”, Kearney Foundation Special Report, UC-Riverside and CAL-EPA DTSC, March 1996.

3.3 Screening Sites with Multiple Pollutants

A suggested stepwise approach for PRG-screening of sites with multiple pollutants is as follows:

- Perform an extensive records search and compile existing data.
- Identify site contaminants in the PRG table. Record the PRG concentrations for various media and note whether PRG is based on cancer risk (indicated by "ca") or noncancer hazard (indicated by "nc"). Segregate cancer PRGs from non-cancer PRGs and exclude (but don't eliminate) non-risk based PRGs ("sat" or "max").
- For cancer risk estimates, take the site-specific concentration (maximum or 95 UCL) and divide by the PRG concentrations that are designated for cancer evaluation ("ca"). Multiply this ratio by 10^{-6} to estimate chemical-specific risk for a reasonable maximum exposure (RME). For multiple pollutants, simply add the risk for each chemical:

$$Risk = [(\frac{conc_x}{PRG_x}) + (\frac{conc_y}{PRG_y}) + (\frac{conc_z}{PRG_z})] \times 10^{-6}$$

- For non-cancer hazard estimates. Divide the concentration term by its respective non-cancer PRG designated as "nc" and sum the ratios for multiple contaminants. The cumulative ratio represents a non-carcinogenic hazard index (HI). A hazard index of 1 or less is generally considered "safe". A ratio greater than 1 suggests further evaluation. **[Note that carcinogens may also have an associated non-cancer PRG that is not listed in the printed copy of the table sent to folks on the mailing list. To obtain these values, the user should view or download the PRG table at our website and display the appropriate sections.]**

$$Hazard\ Index = [(\frac{conc_x}{PRG_x}) + (\frac{conc_y}{PRG_y}) + (\frac{conc_z}{PRG_z})]$$

For more information on screening site risks, the reader should contact EPA Region 9's Technical Support Team.

3.4 Potential Problems

As with any risk-based tool, the potential exists for misapplication. In most cases the root cause will be a lack of understanding of the intended use of Region 9 PRGs. In order to prevent misuse of PRGs, the following should be avoided:

- Applying PRGs to a site without adequately developing a conceptual site model that identifies relevant exposure pathways and exposure scenarios,
- Not considering background concentrations when choosing PRGs as cleanup goals,
- Use of PRGs as cleanup levels without the nine-criteria analysis specified in the

National Contingency Plan (or, comparable analysis for programs outside of Superfund),

- Use of PRGs as cleanup levels without verifying numbers with a toxicologist or regional risk assessor,

Use of antiquated PRG tables that have been superseded by more recent publications,

- Not considering the effects of additivity when screening multiple chemicals, and
- Adjusting PRGs upward by factors of 10 or 100 without consulting a toxicologist or regional risk assessor.

4.0 TECHNICAL SUPPORT DOCUMENTATION

Region 9 PRGs consider human exposure hazards to chemicals from contact with contaminated soils, air, and water. The emphasis of the PRG equations and technical discussion are aimed at developing screening criteria for soils, since this is an area where few standards exist. For air and water, additional reference concentrations or standards are available for many chemicals (e.g. MCLs, non-zero MCLGs, AWQC, and NAAQS) and consequently the discussion of these media are brief.

4.1 Soils - Direct Ingestion

Calculation of risk-based PRGs for direct ingestion of soil is based on methods presented in RAGS HHEM, Part B (USEPA 1991a) and *Soil Screening Guidance* (USEPA 1996a,b, USEPA 2001a). Briefly, these methods backcalculate a soil concentration level from a target risk (for carcinogens) or hazard quotient (for noncarcinogens).

Residential Soil PRGs

A number of studies have shown that inadvertent ingestion of soil is common among children 6 years old and younger (Calabrese et al. 1989, Davis et al. 1990, Van Wijnen et al. 1990). To take into account the higher soil intake rate for children, two different approaches are used to estimate PRGs, depending on whether the adverse health effect is cancer or some effect other than cancer.

For carcinogens, the method for calculating PRGs uses an age-adjusted soil ingestion factor that takes into account the difference in daily soil ingestion rates, body weights, and exposure duration for children from 1 to 6 years old and others from 7 to 31 years old. This health-protective approach is chosen to take into account the higher daily rates of soil ingestion in children as well as the longer duration of exposure that is anticipated for a long-term resident. For more on this method, see USEPA RAGs Part B (1991a).

For noncarcinogenic concerns, the more protective method of calculating a soil PRG is to evaluate childhood exposures separately from adult exposures. In other words, an age-adjustment factor is not applied as was done for carcinogens. This approach is considered conservative because it combines the higher 6-year exposure for children with chronic toxicity criteria. In their analysis of the method, the Science Advisory Board (SAB) indicated that, for most chemicals, the approach may be overly

protective. However, they noted that there are specific instances when the chronic RfD may be based on endpoints of toxicity that are specific to children (e.g. fluoride and nitrates) or when the dose-response is steep (i.e., the dosage difference between the no-observed-adverse-effects level [NOAEL] and an adverse effects level is small). Thus, for the purposes of screening, EPA Region 9 has adopted this approach for calculating soil PRGs for noncarcinogenic health concerns.

Industrial Soil PRGs

In the new *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (Supplemental SSL Guidance, EPA 2001a), two different soil ingestion rates are assumed for non-construction workers: 100 mg/day is assumed for outdoor workers whereas 50 mg/day is assumed for indoor workers. The default value of 100 mg/day for outdoor workers is also recommended by EPA's Technical Review Workgroup for Lead (TRW), and it reflects increased exposures to soils for outdoor workers relative to their indoor counterparts. For more on this, please see the Supplemental SSL Guidance available at the following website:

<http://www.epa.gov/superfund/resources/soil/index.htm>

Because the Region 9 PRGs are generic and intended for screening sites early in the investigation process (often before site-specific information is available), we have chosen to use the 100 mg/day soil ingestion (i.e. outdoor worker) assumption to calculate industrial soil PRGs. Please note that previous issues of the Region 9 PRGs table assumed 50 mg/day soil ingestion rate for workers. This change in soil ingestion rates is reflected in a somewhat lower (more stringent) industrial soils PRG for many contaminants. The appropriateness of this assumption for a particular site may be evaluated when additional information becomes available regarding site conditions or site development.

4.2 Soils - Vapor and Particulate Inhalation

Agency toxicity criteria indicate that risks from exposure to some chemicals via inhalation far outweigh the risk via ingestion; therefore soil PRGs have been designed to address this pathway as well. The models used to calculate PRGs for inhalation of volatiles/particulates are updates of risk assessment methods presented in RAGS Part B (USEPA 1991a) and are identical to the *Soil Screening Guidance: User's Guide and Technical Background Document* (USEPA 1996a,b).

It should be noted that the soil-to-air pathway that is evaluated in the PRGs calculations is based on direct inhalation exposures that result from the volatilization or particulate emissions of chemicals from soil to outdoor air. The soil PRG calculations currently do not evaluate potential for volatile contaminants in soil to migrate indoors. For this evaluation, a site-specific assessment is required because the applicable model, the Johnson and Ettinger model, is extremely sensitive to a number of model parameters that do not lend themselves to standardization on a national basis. For more information on the indoor air model and/or to download a copy, please go to:

http://www.epa.gov/oerrpage/superfund/programs/risk/airmodel/johnson_ettinger.htm

To address the soil-to-outdoor air pathways, the PRG calculations incorporate volatilization factors (VF_s) for volatile contaminants and particulate emission factors (PEF) for nonvolatile contaminants. These factors relate soil contaminant concentrations to air contaminant concentrations that may be inhaled on-site. The VF_s and PEF equations can be broken into two separate models: an emission model to estimate emissions of the contaminant from the soil and a dispersion model to simulate the dispersion of the contaminant in the atmosphere.

The box model in RAGS Part B has been replaced with a dispersion term (Q/C) derived from a modeling exercise using meteorological data from 29 locations across the United States because the box model may not be applicable to a broad range of site types and meteorology and does not utilize state-of-the-art techniques developed for regulatory dispersion modeling. The dispersion model for both volatiles and particulates is the AREA-ST, an updated version of the Office of Air Quality Planning and Standards, Industrial Source Complex Model, ISC2. However, different Q/C terms are used in the VF and PEF equations. Los Angeles was selected as the 90th percentile data set for volatiles and Minneapolis was selected as the 90th percentile data set for fugitive dusts (USEPA1996 a,b). A default source size of 0.5 acres was chosen for the PRG calculations. This is consistent with the default exposure area over which Region 9 typically averages contaminant concentrations in soils. If unusual site conditions exist such that the area source is substantially larger than the default source size assumed here, an alternative Q/C could be applied (see USEPA 1996a,b).

Volatilization Factor for Soils

Volatile chemicals, defined as those chemicals having a Henry's Law constant greater than 10^{-5} (atm-m³/mol) and a molecular weight less than 200 g/mole, were screened for inhalation exposures using a volatilization factor for soils (VF_s). Please note that VF_s 's are available at our website.

The emission terms used in the VF_s are chemical-specific and were calculated from physical-chemical information obtained from several sources. The priority of these sources were as follows: *Soil Screening Guidance* (USEPA 1996a,b), *Superfund Chemical Data Matrix* (USEPA 1996c), *Fate and Exposure Data* (Howard 1991), *Subsurface Contamination Reference Guide* (EPA 1990a), and *Superfund Exposure Assessment Manual* (SEAM, EPA 1988). When there was a choice between a measured or a modeled value (e.g. Koc), we went with modeled values. In those cases where Diffusivity Coefficients (D_i) were not provided in existing literature, D_i 's were calculated using Fuller's Method described in SEAM. A surrogate term was required for some chemicals that lacked physico-chemical information. In these cases, a proxy chemical of similar structure was used that may over- or under-estimate the PRG for soils.

Equation 4-9 forms the basis for deriving generic soil PRGs for the inhalation pathway. The following parameters in the standardized equation can be replaced with specific site data to develop a simple site-specific PRG

- Source area
- Average soil moisture content
- Average fraction organic carbon content
- Dry soil bulk density

The basic principle of the VF_s model (Henry's law) is applicable only if the soil contaminant concentration is at or below soil saturation "sat". Above the soil saturation limit, the model cannot predict an accurate VF-based PRG. How these particular cases are handled, depends on whether the contaminant is liquid or solid at ambient soil temperatures (see Section 4.5).

Particulate Emission Factor for Soils

Inhalation of chemicals adsorbed to respirable particles (PM_{10}) were assessed using a default PEF equal to $1.316 \times 10^9 \text{ m}^3/\text{kg}$ that relates the contaminant concentration in soil with the concentration of respirable particles in the air due to fugitive dust emissions from contaminated soils. The generic PEF was derived using default values in Equation 4-11, which corresponds to a receptor point concentration of approximately $0.76 \text{ ug}/\text{m}^3$. The relationship is derived by Cowherd (1985) for a rapid assessment procedure applicable to a typical hazardous waste site where the surface contamination provides a relatively continuous and constant potential for emission over an extended period of time (e.g. years). This represents an annual average emission rate based on wind erosion that should be compared with chronic health criteria; it is not appropriate for evaluating the potential for more acute exposures.

The impact of the PEF on the resultant PRG concentration (that combines soil exposure pathways for ingestion, skin contact, and inhalation) can be assessed by accessing the Region 9 PRG website and viewing the pathway-specific soil concentrations. Equation 4-11 forms the basis for deriving a generic PEF for the inhalation pathway. For more details regarding specific parameters used in the PEF model, the reader is referred to *Soil Screening Guidance: Technical Background Document* (USEPA 1996a).

Note: the generic PEF evaluates windborne emissions and does not consider dust emissions from traffic or other forms of mechanical disturbance that could lead to greater emissions than assumed here.

4.3 Soils - Dermal Exposure

Dermal Contact Assumptions

Exposure factors for dermal contact with soil are based on recommendations in "Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim Guidance" (USEPA 2001b). Recommended RME (reasonable maximum exposure) defaults for adult workers' skin surface areas ($3300 \text{ cm}^2/\text{day}$) and soil adherence factors ($0.2 \text{ mg}/\text{cm}^2$) now differ from the defaults recommended for adult residents ($5700 \text{ cm}^2/\text{day}$, $0.07 \text{ mg}/\text{cm}^2$) as noted in Exhibit 4-1. This is due to differences in the range of activities experienced by workers versus residents.

Dermal Absorption

Chemical-specific skin absorption values recommended by the Superfund Dermal Workgroup were applied when available. Chemical-specific values are included for the following chemicals: arsenic, cadmium, chlordane, 2,4-D, DDT, lindane, TCDD, PAHs, PCBs, and pentachlorophenols.

The “Supplemental Guidance for Dermal Risk Assessment” (USEPA 2001b) recommends a default dermal absorption factor for semivolatile organic compounds of 10% as a screening method for the majority of SVOCs without dermal absorption factors. Default dermal absorption values for other chemicals (VOCs and inorganics) are not recommended in this new guidance. Therefore, the assumption of 1% for inorganics and 10% for volatiles is no longer included in the Region 9 PRG table. This change has minimal impact on the final risk-based calculations because human exposure to VOCs and inorganics in soils is generally driven by other pathways of exposure.

4.4 Soils - Migration to Groundwater

The methodology for calculating SSLs for the migration to groundwater was developed to identify chemical concentrations in soil that have the potential to contaminate groundwater. Migration of contaminants from soil to groundwater can be envisioned as a two-stage process: (1) release of contaminant in soil leachate and (2) transport of the contaminant through the underlying soil and aquifer to a receptor well. The SSL methodology considers both of these fate and transport mechanisms.

SSLs are backcalculated from acceptable ground water concentrations (i.e. nonzero MCLGs, MCLs, or risk-based PRGs). First, the acceptable groundwater concentration is multiplied by a dilution factor to obtain a target leachate concentration. For example, if the dilution factor is 10 and the acceptable ground water concentration is 0.05 mg/L, the target soil leachate concentration would be 0.5 mg/L. The partition equation (presented in the *Soil Screening Guidance* document) is then used to calculate the total soil concentration (i.e. SSL) corresponding to this soil leachate concentration.

The SSL methodology was designed for use during the early stages of a site evaluation when information about subsurface conditions may be limited. Because of this constraint, the methodology is based on conservative, simplifying assumptions about the release and transport of contaminants in the subsurface. For more on SSLs, and how to calculate site-specific SSLs versus generic SSLs presented in the PRG table, the reader is referred to the *Soil Screening Guidance* document (USEPA 1996a,b).

4.5 Soil Saturation Limit

The soil saturation concentration “sat” corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the soil contaminant may be present in free phase, i.e., nonaqueous phase liquids (NAPLs) for contaminants that are liquid at ambient soil temperatures and pure solid phases for compounds that are solid at ambient soil temperatures.

Equation 4-10 is used to calculate “sat” for each volatile contaminant. As an update to RAGS HHEM, Part B (USEPA 1991a), this equation takes into account the amount of contaminant that is in the vapor phase in soil in addition to the amount dissolved in the soil’s pore water and sorbed to soil particles.

Chemical-specific “sat” concentrations must be compared with each VF-based PRG because a basic principle of the PRG volatilization model is not applicable when free-phase contaminants are present. How these cases are handled depends on whether the contaminant is liquid or solid at ambient

temperatures. Liquid contaminant that have a VF-based PRG that exceeds the “sat” concentration are set equal to “sat” whereas for solids (e.g., PAHs), soil screening decisions are based on the appropriate PRGs for other pathways of concern at the site (e.g., ingestion).

4.6 Tap Water - Ingestion and Inhalation

Calculation of PRGs for ingestion and inhalation of contaminants in domestic water is based on the methodology presented in RAGS HHEM, Part B (USEPA 1991a). Ingestion of drinking water is an appropriate pathway for all chemicals. For the purposes of this guidance, however, inhalation of volatile chemicals from water is considered routinely only for chemicals with a Henry’s Law constant of 1×10^{-5} atm-m³/mole or greater and with a molecular weight of less than 200 g/mole.

For volatile chemicals, an upperbound volatilization constant (VF_w) is used that is based on all uses of household water (e.g. showering, laundering, and dish washing). Certain assumptions were made. For example, it is assumed that the volume of water used in a residence for a family of four is 720 L/day, the volume of the dwelling is 150,000 L and the air exchange rate is 0.25 air changes/hour (Andelman in RAGS Part B). Furthermore, it is assumed that the average transfer efficiency weighted by water use is 50 percent (i.e. half of the concentration of each chemical in water will be transferred into air by all water uses). Note: the range of transfer efficiencies extends from 30% for toilets to 90% for dishwashers.

4.7 Default Exposure Factors

Default exposure factors were obtained primarily from RAGS Supplemental Guidance Standard Default *Exposure Factors* (OSWER Directive, 9285.6-03) dated March 25, 1991 and more recent information from U.S. EPA's Office of Solid Waste and Emergency Response, U.S. EPA's Office of Research and Development, and California EPA's Department of Toxic Substances Control (see Exhibit 4-1).

Because contact rates may be different for children and adults, carcinogenic risks during the first 30 years of life were calculated using age-adjusted factors ("adj"). Use of age-adjusted factors are especially important for soil ingestion exposures, which are higher during childhood and decrease with age. However, for purposes of combining exposures across pathways, additional age-adjusted factors are used for inhalation and dermal exposures. These factors approximate the integrated exposure from birth until age 30 combining contact rates, body weights, and exposure durations for two age groups - small children and adults. Age-adjusted factors were obtained from RAGS PART B or developed by analogy (see derivations next page).

For soils only, noncarcinogenic contaminants are evaluated in children separately from adults. No age-adjustment factor is used in this case. The focus on children is considered protective of the higher daily intake rates of soil by children and their lower body weight. For maintaining consistency when evaluating soils, dermal and inhalation exposures are also based on childhood contact rates.

(1) ingestion([mg-yr]/[kg-d]):

$$IFS_{adj} = \frac{ED_c \times IRS_c}{BW_c} + \frac{(ED_r - ED_c) \times IRS_a}{BW_a}$$

(2) skin contact([mg-yr]/[kg-d]):

$$SFS_{adj} = \frac{ED_c \times AF \times SA_c}{BW_c} + \frac{(ED_r - ED_c) \times AF \times SA_a}{BW_a}$$

(3) inhalation ([m³-yr]/[kg-d]):

$$InhF_{adj} = \frac{ED_c \times IRA_c}{BW_c} + \frac{(ED_r - ED_c) \times IRA_a}{BW_a}$$

EXHIBIT 4-1 STANDARD DEFAULT FACTORS

<u>Symbol</u>	<u>Definition (units)</u>	<u>Default</u>	<u>Reference</u>
CSFo	Cancer slope factor oral (mg/kg-d) ⁻¹	--	IRIS, HEAST, or NCEA
CSFi	Cancer slope factor inhaled (mg/kg-d) ⁻¹	--	IRIS, HEAST, or NCEA
RfDo	Reference dose oral (mg/kg-d)	--	IRIS, HEAST, or NCEA
RfDi	Reference dose inhaled (mg/kg-d)	--	IRIS, HEAST, or NCEA
TR	Target cancer risk	10 ⁻⁶	--
THQ	Target hazard quotient	1	--
BWa	Body weight, adult (kg)	70	RAGS (Part A), EPA 1989 (EPA/540/1-89/002)
BWc	Body weight, child (kg)	15	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
ATc	Averaging time - carcinogens (days)	25550	RAGS(Part A), EPA 1989 (EPA/540/1-89/002)
ATn	Averaging time - noncarcinogens (days)	ED*365	
SAa	Exposed surface area for soil/dust (cm ² /day) – adult resident	5700	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
	– adult worker	3300	
SAc	Exposed surface area, child in soil (cm ² /day)	2800	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
AFa	Adherence factor, soils (mg/cm ²) – adult resident	0.07	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
	– adult worker	0.2	
AFc	Adherence factor, child (mg/cm ²)	0.2	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
ABS	Skin absorption defaults (unitless): – semi-volatile organics	0.1	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
	– volatile organics	--	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
	– inorganics	--	Dermal Assessment, EPA 2000 (EPA/540/R-99/005)
IRaA	Inhalation rate - adult (m ³ /day)	20	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
IRAc	Inhalation rate - child (m ³ /day)	10	Exposure Factors, EPA 1997 (EPA/600/P-95/002Fa)
IRWa	Drinking water ingestion - adult (L/day)	2	RAGS(Part A), EPA 1989 (EPA/540/1-89/002)
IRWc	Drinking water ingestion - child (L/day)	1	PEA, Cal-EPA (DTSC, 1994)
IRSa	Soil ingestion - adult (mg/day)	100	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
IRSc	Soil ingestion - child (mg/day),	200	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
IRSo	Soil ingestion - occupational (mg/day)	100	Soil Screening Guidance (EPA 2001a)
EFr	Exposure frequency - residential (d/y)	350	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
EFO	Exposure frequency - occupational (d/y)	250	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
EDr	Exposure duration - residential (years)	30 ^a	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
EDc	Exposure duration - child (years)	6	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
EDo	Exposure duration - occupational (years)	25	Exposure Factors, EPA 1991 (OSWER No. 9285.6-03)
	Age-adjusted factors for carcinogens:		
IFSadj	Ingestion factor, soils ([mg-yr]/[kg-d])	114	RAGS(Part B), EPA 1991 (OSWER No. 9285.7-01B)
SFSadj	Dermal factor, soils ([mg-yr]/[kg-d])	361	By analogy to RAGS (Part B)
InhFadj	Inhalation factor, air ([m ³ -yr]/[kg-d])	11	By analogy to RAGS (Part B)
IFWadj	Ingestion factor, water ([L-yr]/[kg-d])	1.1	By analogy to RAGS (Part B)
VFw	Volatilization factor for water (L/m ³)	0.5	RAGS(Part B), EPA 1991 (OSWER No. 9285.7-01B)
PEF	Particulate emission factor (m ³ /kg)	See below	Soil Screening Guidance (EPA 1996a,b)
VF _s	Volatilization factor for soil (m ³ /kg)	See below	Soil Screening Guidance (EPA 1996a,b)
sat	Soil saturation concentration (mg/kg)	See below	Soil Screening Guidance (EPA 1996a,b)

Footnote:

^aExposure duration for lifetime residents is assumed to be 30 years total. For carcinogens, exposures are combined for children (6 years) and adults (24 years) .

4.8 Standardized Equations

The equations used to calculate the PRGs for carcinogenic and noncarcinogenic contaminants are presented in Equations 4-1 through 4-8. The PRG equations update RAGS Part B equations. The methodology backcalculates a soil, air, or water concentration level from a target risk (for carcinogens) or hazard quotient (for noncarcinogens). For completeness, the soil equations combine risks from ingestion, skin contact, and inhalation simultaneously. **Note: the electronic version of the table also includes pathway-specific PRGs, should the user decide against combining specific exposure pathways; or, the user wants to identify the relative contribution of each pathway to exposure.**

To calculate PRGs for volatile chemicals in soil, a chemical-specific volatilization factor is calculated per Equation 4-9. Because of its reliance on Henry's law, the VF_s model is applicable only when the contaminant concentration in soil is at or below saturation (i.e. there is no free-phase contaminant present). Soil saturation ("sat") corresponds to the contaminant concentration in soil at which the adsorptive limits of the soil particles and the solubility limits of the available soil moisture have been reached. Above this point, pure liquid-phase contaminant is expected in the soil. If the PRG calculated using VF_s was greater than the calculated sat, the PRG was set equal to sat, in accordance with *Soil Screening Guidance* (USEPA 1996 a,b). The equation for deriving sat is presented in Equation 4-10.

PRG EQUATIONS

Soil Equations: For soils, equations were based on three exposure routes (ingestion, skin contact, and inhalation).

Equation 4-1: Combined Exposures to Carcinogenic Contaminants in Residential Soil

$$C(\text{mg/kg}) = \frac{TR \times AT_c}{EF_r \left[\left(\frac{IFS_{adj} \times CSF_o}{10^6 \text{mg/kg}} \right) + \left(\frac{SFS_{adj} \times ABS \times CSF_o}{10^6 \text{mg/kg}} \right) + \left(\frac{InhF_{adj} \times CSF_i}{VF_s^a} \right) \right]}$$

Equation 4-2: Combined Exposures to Noncarcinogenic Contaminants in Residential Soil

$$C(\text{mg/kg}) = \frac{THQ \times BW_c \times AT_n}{EF_r \times ED_c \left[\left(\frac{1}{RfD_o} \times \frac{IRS_c}{10^6 \text{mg/kg}} \right) + \left(\frac{1}{RfD_o} \times \frac{SA_c \times AF \times ABS}{10^6 \text{mg/kg}} \right) + \left(\frac{1}{RfD_i} \times \frac{IRA_c}{VF_s^a} \right) \right]}$$

Equation 4-3: Combined Exposures to Carcinogenic Contaminants in Industrial Soil

$$C(\text{mg/kg}) = \frac{TR \times BW_a \times AT_c}{EF_o \times ED_o \left[\left(\frac{IRS_o \times CSF_o}{10^6 \text{mg/kg}} \right) + \left(\frac{SA_a \times AF \times ABS \times CSF_o}{10^6 \text{mg/kg}} \right) + \left(\frac{IRA_a \times CSF_i}{VF_s^a} \right) \right]}$$

Footnote:

^aUse VF_s for volatile chemicals (defined as having a Henry's Law Constant [atm-m³/mol] greater than 10⁻⁵ and a molecular weight less than 200 grams/mol) or PEF for non-volatile chemicals.

Equation 4-4: Combined Exposures to Noncarcinogenic Contaminants in Industrial Soil

$$C(\text{mg/kg}) = \frac{THQ \times BW_a \times AT_n}{EF_o \times ED_o \left[\left(\frac{1}{RfD_o} \times \frac{IRS_o}{10^6 \text{mg/kg}} \right) + \left(\frac{1}{RfD_o} \times \frac{SA_a \times AF \times ABS}{10^6 \text{mg/kg}} \right) + \left(\frac{1}{RfD_i} \times \frac{IRA_a}{VF_s^a} \right) \right]}$$

Tap Water Equations:

Equation 4-5: Ingestion and Inhalation Exposures to Carcinogenic Contaminants in Water

$$C(\text{ug/L}) = \frac{TR \times AT_c \times 1000 \text{ug/mg}}{EF_r \left[(IFW_{adj} \times CSF_o) + (VF_w \times InhF_{adj} \times CSF_i) \right]}$$

Equation 4-6: Ingestion and Inhalation Exposures to Noncarcinogenic Contaminants in Water

$$C(\text{ug/L}) = \frac{THQ \times BW_a \times AT_n \times 1000 \text{ug/mg}}{EF_r \times ED_r \left[\left(\frac{IRW_a}{RfD_o} \right) + \left(\frac{VF_w \times IRA_a}{RfD_i} \right) \right]}$$

Air Equations:

Equation 4-7: Inhalation Exposures to Carcinogenic Contaminants in Air

$$C(\text{ug/m}^3) = \frac{TR \times AT_c \times 1000 \text{ug/mg}}{EF_r \times InhF_{adj} \times CSF_i}$$

Equation 4-8: Inhalation Exposures to Noncarcinogenic Contaminants in Air

$$C(\text{ug/m}^3) = \frac{THQ \times RfD_i \times BW_a \times AT_n \times 1000 \text{ug/mg}}{EF_r \times ED_r \times IRA_a}$$

Footnote:

^aUse VF_s for volatile chemicals (defined as having a Henry's Law Constant [atm-m³/mol] greater than 10⁻⁵ and a molecular weight less than 200 grams/mol) or PEF for non-volatile chemicals.

SOIL-TO-AIR VOLATILIZATION FACTOR (VF_s)

Equation 4-9: Derivation of the Volatilization Factor

$$VF_s (m^3/kg) = (Q/C) \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4} (m^2/cm^2)$$

where:

$$D_A = \frac{[(\Theta_a^{10/3} D_i H' + \Theta_w^{10/3} D_w) / n^2]}{\rho_b K_d + \Theta_w + \Theta_a H'}$$

<u>Parameter</u>	<u>Definition (units)</u>	<u>Default</u>
VF _s	Volatilization factor (m ³ /kg)	--
D _A	Apparent diffusivity (cm ² /s)	--
Q/C	Inverse of the mean conc. at the center of a 0.5-acre square source (g/M ² -s per kg/m ³)	68.81
T	Exposure interval (s)	9.5 x 10 ⁸
ρ _b	Dry soil bulk density (g/cm ³)	1.5
Θ _a	Air filled soil porosity (L _{air} /L _{soil})	0.28 or n-Θ _w
n	Total soil porosity (L _{pore} /L _{soil})	0.43 or 1 - (ρ _b /ρ _s)
Θ _w	Water-filled soil porosity (L _{water} /L _{soil})	0.15
ρ _s	Soil particle density (g/cm ³)	2.65
D _i	Diffusivity in air (cm ² /s)	Chemical-specific
H	Henry's Law constant (atm-m ³ /mol)	Chemical-specific
H'	Dimensionless Henry's Law constant	Calculated from H by multiplying by 41 (USEPA 1991a)
D _w	Diffusivity in water (cm ² /s)	Chemical-specific
K _d	Soil-water partition coefficient (cm ³ /g) = K _{oc} f _{oc}	Chemical-specific
K _{oc}	Soil organic carbon-water partition coefficient (cm ³ /g)	Chemical-specific
f _{oc}	Fraction organic carbon in soil (g/g)	0.006 (0.6%)

SOIL SATURATION CONCENTRATION (sat)

Equation 4-10: Derivation of the Soil Saturation Limit

$$sat = \frac{S}{\rho_b} (K_d \rho_b + \Theta_w + H' \Theta_a)$$

<u>Parameter</u>	<u>Definition (units)</u>	<u>Default</u>
sat	Soil saturation concentration (mg/kg)	--
S	Solubility in water (mg/L-water)	Chemical-specific
ρ_b	Dry soil bulk density (kg/L)	1.5
n	Total soil porosity (L_{pore}/L_{soil})	0.43 or $1 - (\rho_b/\rho_s)$
ρ_s	Soil particle density (kg/L)	2.65
K_d	Soil-water partition coefficient (L/kg)	$K_{oc} \times f_{oc}$ (chemical-specific)
k_{oc}	Soil organic carbon/water partition coefficient (L/kg)	Chemical-specific
f_{oc}	Fraction organic carbon content of soil (g/g)	0.006 or site-specific
Θ_w	Water-filled soil porosity (L_{water}/L_{soil})	0.15
Θ_a	Air filled soil porosity (L_{air}/L_{soil})	0.28 or $n - \Theta_w$
w	Average soil moisture content (kg_{water}/kg_{soil} or L_{water}/kg_{soil})	0.1
H	Henry's Law constant (atm-m ³ /mol)	Chemical-specific
H'	Dimensionless Henry's Law constant	$H \times 41$, where 41 is a units conversion factor

SOIL-TO-AIR PARTICULATE EMISSION FACTOR (PEF)

Equation 4-11: Derivation of the Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3600s/h}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}$$

<u>Parameter</u>	<u>Definition (units)</u>	<u>Default</u>
PEF	Particulate emission factor (m ³ /kg)	1.316 x 10 ⁹
Q/C	Inverse of the mean concentration at the center of a 0.5-acre-square source (g/M ² -s per kg/m ³)	90.80
V	Fraction of vegetative cover (unitless)	0.5
U _m	Mean annual windspeed (m/s)	4.69
U _t	Equivalent threshold value of windspeed at 7 m (m/s)	11.32
F(x)	Function dependent on U _m /U _t derived using Cowherd (1985) (unitless)	0.194

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