

January 2010

## Urban Fill Characterization And Risk-Based Management Decisions - A Practical Guide

William R. Swanson  
CDM

Pamela Lamie  
CDM

Follow this and additional works at: <http://scholarworks.umass.edu/soilsproceedings>

---

### Recommended Citation

Swanson, William R. and Lamie, Pamela (2010) "Urban Fill Characterization And Risk-Based Management Decisions - A Practical Guide," *Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy*: Vol. 12 , Article 9.  
Available at: <http://scholarworks.umass.edu/soilsproceedings/vol12/iss1/9>

This Conference Proceeding is brought to you for free and open access by ScholarWorks@UMass Amherst. It has been accepted for inclusion in Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy by an authorized editor of ScholarWorks@UMass Amherst. For more information, please contact [scholarworks@library.umass.edu](mailto:scholarworks@library.umass.edu).

## **PART IV: Brownfields**

### **Chapter 8**

#### **URBAN FILL CHARACTERIZATION AND RISK-BASED MANAGEMENT DECISIONS - A PRACTICAL GUIDE**

*Draft*

William R. Swanson and Pamela Lamie

*CDM, 50 Hampshire Street, Cambridge, MA 02139 Tel: 617-452-6274, E-mail: swansonwr@cdm.com and lamiepo@cdm.com*

**Abstract:** This paper examines contaminants in urban fill soil via background concentrations, disposal facility parameters and limits, and no-significant risk limits for site closure. It provides a guide when considering what might be expected at brownfields sites and how the findings at a site may be used to make practical soil management decisions. The approach is based on experience in Massachusetts following Massachusetts Department of Environmental Protection (MassDEP) regulations and guidance.

It is evident that urban fill soil may be expected to contain contaminants, in particular, heavy metals and polynuclear aromatic hydrocarbons, from specific releases and background sources. Natural concentrations and background concentrations are important sorting and selection criteria in evaluating which chemicals should be selected for analysis and which should be considered background. This paper discusses lead, arsenic, carcinogenic polynuclear aromatic hydrocarbons, dioxins, polychlorinated biphenyls, and asbestos. The authors outline each contaminant, the usual range in natural and urban fill soils, and its risk-based or related thresholds, with emphasis on the New England area. The outcome is a range of concentrations that can be used as a guide when considering brownfields sites such that their information may be compared to the ranges and brought into meaningful focus.

**Key words:** lead, arsenic, carcinogenic polynuclear aromatic hydrocarbons, dioxins, polychlorinated biphenyls, and asbestos

#### **1. INTRODUCTION**

The evaluation of numerous sites characterized by the presence of urban fill has revealed that there are several key contaminants, particularly, lead, arsenic, and polynuclear aromatic hydrocarbons (PAHs) that are consistently present at a high frequency. Other key contaminants, such as polychlorinated biphenyls (PCBs), may be detected less frequently. Dioxin, which is analyzed relatively infrequently, may also drive potential human health risks when present in urban fill. These constituents are also subject to environmental regulations at the national, state, and sometimes at the local level.

To determine if the concentration of a particular key contaminant is relatively “high” or “low,” there are three status areas or zones that may be defined based on the potential for human health risk. The first zone is a No Significant Risk level. From a human health perspective, a condition of No Significant Risk has been achieved if cumulative noncancer risk is calculated at a Hazard Index of one

and if cumulative cancer risk is at a level of not more than one additional cancer occurrence per 100,000 persons. Any given background concentration, either naturally occurring or anthropogenic, may fall into the risk-based No Significant Risk zone or could potentially fall into the second Probable (Potential) Risk zone. Further along the scale are “acute” levels such as would cause a risk if present for a short-period of time (called an Imminent Hazard by (Massachusetts Department of Environmental Protection (MassDEP)) or the upper concentration limit (UCL), defined by MassDEP as a potential long-term or future risk to public welfare—health, safety, and the environment. In this assessment, each of the key urban fill contaminants is defined by these zones or status areas: using a “green” zone, within which there is little likelihood of significant risk; a “yellow,” or cautionary zone, where risk may occur, but might be dealt with by institutional controls—or capping, venting, and containment; and a “red” zone, where remedial actions in the form of reduction, removal, or very robust, costly impediments to contact are required. Nothing about these ranges is absolute—they are based on the judgment of the authors and are thresholds or guiding values for an initial assessment or interpretation, subject to refinement by a professional risk assessor and the specifics of applicable regulations.

The selection of these zones is based on an extensive literature search of the following:

1. Background levels in the literature based on either naturally occurring concentrations or widespread anthropogenic occurrence;
2. Risk-based concentrations based on residential direct contact with soil computed using MassDEP methods (MassDEP, 2006);
3. State and federal standards and Preliminary Remediation Goals (PRGs) based on either human health risk, background, achievable detection limits, or other considerations; and
4. Upper bound levels or cut-off limits above which a risk is considered inevitable based on a short-term exposure scenario or a long-term potential or acute threat to the environment.

## 2. MATERIAL AND METHODS FOR SELECTION OF KEY CONTAMINANTS

The following selected parameters/contaminants are presented in the paper in alphabetical order: arsenic, asbestos, dioxin, lead, PAHs, and PCBs. These parameters/contaminants were selected because they represent key contaminants with background and risk-based concentrations of interest to brownfields, particularly PAHs and lead.

Reasons for contaminant selection are as follows:

- Arsenic and lead are the most problematic of the metals based on our experience with fill in old urban areas and with railroad beds and rural areas affected by historical pesticide use. Some generalizations based on experience are that in urban fill, lead is the metal of concern in a majority of the cases where metals are an issue, including toxicity characteristic leaching procedure (TCLP) failures. Arsenic may occur naturally and was used in lead arsenate pesticides on orchards and herbicides along railroads. Decaying treated timber is another arsenic source. It is rare to find an urban fill site dominated by other metals without one or the other of these metals playing a significant role.
- Asbestos, currently being studied by MassDEP, is soon to be more precisely regulated as an urban fill soil contaminant. The concept of background is worthy of mention in regard to the latest research. It had widespread use for several decades and appears quite regularly in urban fill.
- Dioxin is typically present in urban fill, though not often analyzed for. Its consideration was of interest especially in old urban areas with a long history of burning, especially by waste incineration, up to about 35 years ago.

- PAHs are generally present in urban fill and often affect the overall site risk. When assessing urban releases, their presence from a myriad of sources is often a confounding factor.
- PCBs are generally present, but often at levels below normal cleanup goals or detection limits. However, the regulatory position, persistence, and disposal cost impacts associated with PCBs made them worthy of inclusion in this document.

Hence, arsenic, lead, and PAHs are the primary contaminants of concern in urban fill. PCBs, asbestos, and dioxin have been included to give a more complete and balanced picture. While petroleum contaminants may be widespread constituents in urban fill soils, volatile organic compounds (VOCs) and petroleum contaminants are generally not considered significant risk drivers. Since there are no naturally occurring sources, VOCs tend to volatilize in soil rather than adhere to soil particulates, and heavier petroleum contaminants generally have a relatively low toxicity compared to the other risk drivers. We note, however, that total petroleum hydrocarbon concentrations may be a factor in soil disposal as it is a key regulated disposal parameter.

### 3. RESULTS BACKGROUND

The literature suggests there are a number of definitions that can be applied to the term “background.” One is strictly natural soil that has been unaltered by humans. Such soil would be natural soil in an excavation or pit that had not previously been worked, excavated, affected by air pollution fallout, or affected by contaminated groundwater flow through. The second is natural soil that has been altered by its presence in the urban environment or in widespread agricultural activity. The third is soil in the urban environment that has been extensively altered and contains evident or noticeable debris; asbestos containing material, coal ash, or wood ash, often being locations of old landfills. MassDEP (MassDEP, 2002) has developed well-supported background concentrations, viewed as statistical upper limits for the second and third definitions above and as referenced by contaminant below.

Background can be further described as follows:

1. Truly natural materials, especially arsenic and asbestos mineral groups that can be widespread and of health risk concern, with significant impact potential, not to be ignored on the basis of “natural.”
2. Widespread impacts, such as lead, PCBs, or dioxins that can be at low concentrations in soil over a large area due to the airborne nature of the delivery.
3. “Widespread polluted fill” (CTDEP, RSRs) due to landfilling to dispose of waste to “create land” in urban areas, such as the entire Boston waterfront. When severe fires occurred, the building debris was used as fill, and, sometimes, fire debris or just demolition debris was simply built over. Lead and PAHs are often the risk drivers in this setting. Asbestos may also appear, depending on when landfilling occurred. The most intense use of asbestos occurred from the industrial revolution through the 1970s.

Of the literature values available, PAHs as characterized by benzo(a)pyrene in this effort, seemed the most problematic in terms of defining thresholds. Based on our experience in the Boston urban environment and eastern Massachusetts, this difficulty in defining thresholds was somewhat unexpected. MassDEP (MassDEP, 2002) has established some well-supported background concentrations, but those appear higher than standards or background values in other areas. Since Boston is an older city compared to a number of other locations, these concentrations are probably due to anthropogenic buildup related the longer time period involved in the accumulation or “banking” of the material and substantial burned debris in the fill. In many respects, excepting natural materials, the urban east should usually be above average in this regard.

The terms, “high,” “low,” and so forth when used herein, are relative with reference to risk-based concentrations.

There is no exact number for background that stands out under any listed parameter, as the levels will vary somewhat from location to location. However, some general consensus within an order of magnitude is generally possible and will point the user into “danger (red) and comfort (green) zones.”

All referenced or derived soil concentrations shown on the figures are milligrams/kilogram (mg/kg) (or parts per million (ppm)) dry weight basis except for dioxin which is nanogram/kilogram (ng/kg) (or parts per trillion (ppt)) dry weight basis. As noted, several of the figures (Figures 1, 3, 4, and 5) are color coded, green generally meant to represent an acceptable limit (background or risk based), yellow to represent a caution or problematic concentration limit, and red serves to denote concentrations that are at unacceptable levels. While necessarily imperfect due to the array of sources and approaches, the figures serve as a useful guide to risk-based levels, as well as a guide to background levels in the urban environment. A horizontal arrow on the figure notes that the range may extend across one or both of the established boundaries.

#### **4. RISK-BASED CONCENTRATIONS**

The residential risk-based concentrations that were calculated for the key contaminants (other than asbestos) employed exposure assumptions used in the derivation of MassDEP Soil Standards. The values were set at a 1E-05 (1 excess cancer risk in a population of 100,000 persons). For the evaluation of cancer risk for arsenic, PAHs, dioxin, and PCBs, a 30-year cumulative risk was calculated for three age groups: young children ages 1-8 years, older children 8-18 years old, and adults 18-31 years old. For the evaluation of noncancer risk for lead, the most sensitive age group, young children ages 1-8 years old, were evaluated. For each age group evaluated for the direct contact exposures, including incidental ingestion of soil and dermal contact, it was assumed that exposure occurs approximately 5 times per week for 30 weeks, totaling 150 exposure events per year. For the calculation of dermal risk, a skin surface area was calculated assuming the face, hands, forearms, lower legs and feet would be exposed to soil.

#### **5. DISCUSSION (BY SELECTED CONSTITUENT)**

In the discussion below, we present background values established by others, provide summary comments, a computed risk number and relevant regulatory site remediation, and off-site disposal/or reuse criteria. Each chemical has an associated figure showing the key information. Where the available information was sufficient, the figure is provided with a scale at the bottom indicating three levels with two dividing concentrations. The green level at the lower left is a zone where risk-based and background parameters dominate. Collectively considered these suggest a low potential risk, or at least a tolerable risk. The yellow level between the end of the green to the next number is the zone where there is an appreciable potential risk and some measures will need to be taken. The red level contains the criteria where there is potential for short-term, acute, substantial, or imminent hazard impacts. The red zone contains numbers well above all but rare natural background conditions, such as arsenic-containing rock or natural asbestos.

No Significant (Potential) Risk	Probable (Potential) Risk	Certainty of (Potential) Risk
<b>Background</b>	75 (max.) - Boston Blue Clay, Arsenic in Rock, Worcester Co, MA, Belt	
20 - MA		
11 - NH		
0.02-350 (typically <40) - US -34 states		
Pesticide Use (Homes, Orchards)		100's
Treated Timber Decay (Play equipment, guardrail)		100's (also varies according to original treatment)
0.02-48.9 - NJ		
2-6 Denmark		
ND- 48 Delaware		
14 - Louisiana		
7 - Washington State		
3- 12 - NY		
10-20 - NY		
5 (5,776 samples-ave. extraction test) North Carolina		
2.12 - 26 Texas		
7.9-31 - Tennessee		
2.1-22 - Alluvial Soils Glacial Till & Drift, US		
1.8-31.0, most <20- Oakland, CA		
ND-10-Resuspended Road Dust		
<b>Calculated Risk</b>		
18- residential direct contact (cancer)		
0.06 - veg. growing		
<b>Standards</b>		
20-MA		
11-NH		
7.5-NY		
23 - 0'-2' } Delaware	40-potential imminent hazard (MassDEP, 2006)	200-UCL - exceeds, then permanent solution not possible (MassDEP, 2006)
101- 2'-6' }		
10 -CT		
7 - RI		
20-Denmark		
Residential: 0.1 -250 (typically <20)		
Industrial: 3 - 500 (typically <30)		
(US-34 states)		
<b>Disposal Parameters</b>		
	40 max.- Mass landfills/ Recycle (MassDEP, 2006)	100-TCLP/RCRA Threshold (USEPA)
<b>The Scale: ("cutoffs" or "thresholds")</b>		

Figure 1. Arsenic

Arsenic is a common contaminant in urban fill soils. Arsenic is naturally occurring in soil, but the primary source of widespread contamination is likely from pesticide use. In various urban park projects in Boston totaling more than 300 samples, arsenic was detected in approximately 90 percent

of the fill soil samples collected to characterize the sites. Due to the nature of arsenic's high toxicity to human health (a known carcinogen (EPA, 2006)), natural background and fill background concentrations (at 20 mg/kg) may be higher than actual risk-based concentrations. For example, a residential risk-based concentration at the No Significant Risk level is 18 mg/kg based on direct contact exposures. If the consumption of homegrown produce is considered an additional exposure pathway, then the risk-based concentration is 0.06 mg/kg.

By contrast, background levels may exceed risk-based levels and may even extend into the Potential/Probable Risk zone. The MassDEP background concentration for both natural soils and urban fill soils is 20 mg/kg, slightly higher than the residential risk-based concentration of 18 mg/kg. The 20 mg/kg fill background value was developed from approximately 750 soil samples from downtown Boston as well as some other studies. Natural soils vary from a few mg/kg to more than 40 mg/kg in an arsenic belt in Worcester County, Massachusetts. A concentration of 40 mg/kg is considered significant in Massachusetts as 40 mg/kg may constitute an Imminent Hazard condition, if the arsenic is present in surface soils accessible to young children such as in a residential back yard or a school or playground. Arsenic levels in Boston Blue Clay are often in excess of 40 mg/kg due to its natural mineral content. Soils affected by lead arsenate pesticides are often in excess of 40 mg/kg ranging up to hundreds of mg/kg. The 40 mg/kg limit also applies to soil reuse at Massachusetts in-state lined and unlined landfills under Policy COMM 97-001 (MassDEP, 1997).

As noted on the figure, regulatory standards set to be protective of human health risk are 20 mg/kg in Massachusetts (based on background), 11 mg/kg in New Hampshire (based on background), 10 mg/kg in Connecticut, and 7 mg/kg in Rhode Island. As a useful guide, any concentration less than 10 mg/kg is likely attributable to background, while a concentration greater than 20 mg/kg is likely indicative of a site release, high natural soil depending on local geology, or pesticide use if there is a history of agricultural use. Natural soil would be defined by deeper, undisturbed, native material, while pesticides would likely reside in topsoil.

The MassDEP upper concentration limit (MassDEP, 2006) is 200 mg/kg, at and above which a permanent solution is not possible without further action.

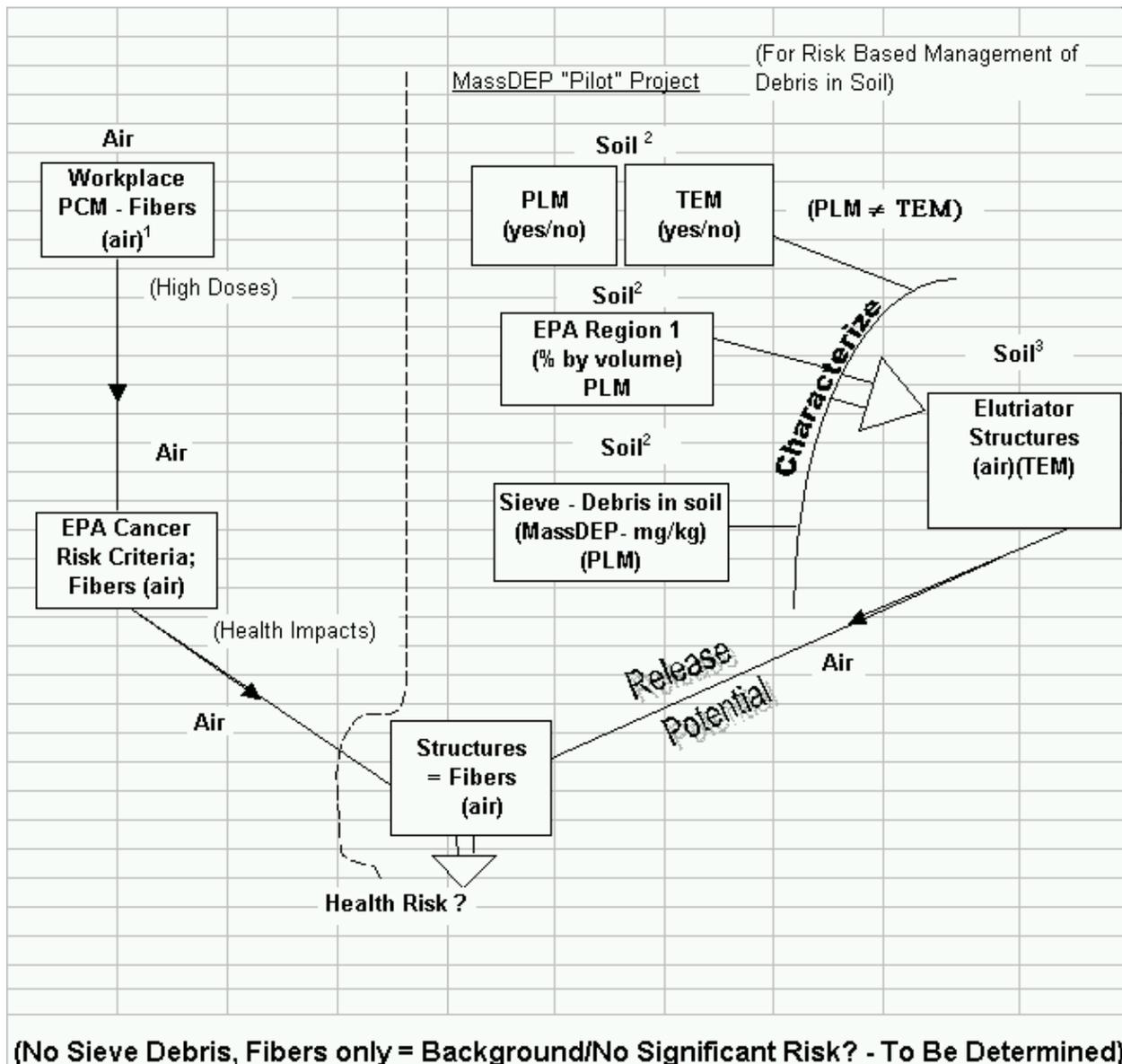


Figure 2. Asbestos

Notes

- 1.) Standards are available for "cleanup."
- 2.) No existing standards, MassDEP currently uses ND as "cleanup criteria."
- 3.) Possible standard development.

**PCM** - Phase Contrast Microscopy  
**PLM** - Polarized Light Microscopy  
**TEM** - Transmission Electron Microscopy

**Air: 0.00001 to 0.0001 fibers/milliliter is "background." (ATSDR 2001)**

The singular background value available is an air concentration noted for urban air quality. Otherwise, the information on Figure 2 illustrates our understanding of the MassDEP approach to sampling and analysis in preparation for additional asbestos regulations regarding impacted soil management and disposal. On the left of the Figure is the U.S. Environmental Protection Agency (USEPA) risk approach/numeric developed by phase contrast microscopy (PCM) data, and to the right is a representation by the authors of their understanding of the latest (draft) MassDEP method coming together as a soil management approach. Some key notes: Three analytical methods are used

and while all microscopy, are not equal. The MassDEP approach is quite functional, but the USEPA numeric is not necessarily comparable. However, all things considered, the approach is the most comprehensive available and is applicable to urban fill soil. As data is generated, more will be known. At this time, scattered fibers without any identifiable debris would probably serve as background.

There is no established background volume percentage or unit weight value in soil and various types of asbestos occur naturally throughout the world. Asbestos is a mineral fiber and comes in different sizes and shapes. Measurement techniques have evolved with microscopic viewing of building material, more recently applied to soil. Generally, if building material contains asbestos at less than 1 percent by volume, it is not considered asbestos containing. MassDEP is well along in establishing protocols for management of urban fill soil with asbestos debris and results to date are well developed but not final. There have been some air background numbers that might relate to soils, but we are not aware of a studied link.

There are large, natural deposits of these physically and chemically varied mineral fibers, particularly in California but with some in New England, notably asbestos mines in Vermont. There have been background or baseline numbers suggested for air, but, not to our knowledge, for soil. The diagram of Figure 2 illustrates the current study approach by MassDEP for urban fill soil containing asbestos debris and having the potential to release fibers to ambient (outdoor) air. While of a preliminary nature, it would appear that if no identified asbestos-containing material (ACM) debris can be sieved out of the soil sample, then there are not likely to be enough fibers present in the soil to cause a concern. The fibers present would be considered background in that respect. The presence of debris would constitute a source material beyond that expected of urban fill soil at background levels, with questions remaining as noted on the figure. A key issue is that USEPA's risk-parameter development is based on results from one measurement approach that does not necessarily correlate with the current methods to detect asbestos in soil or in particular in air generated in the elutriator device.

No Significant (Potential) Risk	Probable (Potential) Risk	Certainty of (Potential) Risk
<b>Background</b>		
Urban Location (0.86 - 80, Ave 17- Eastern, MA) (Impacted with Ash)	50 - (ATSDR 1997) Screening value (max.)	Over 1,000 - (ATSDR 1997) - Action Level
7 (Ontario)		
0.17-9.14 - Rural } 0.54 - 33.0 Urban } New Zealand		
0.77 - 77.4 - New Zealand		
4 - rural } 20-urban } USEPA		
16-189, Ave. 62- Canton, MA	50-100 (ATSDR - 97) Evaluation Levels	
0.21-42.9 - Colorado & Utah		
0.6 - 35 - Michigan		
0.15 - 13.3 - Ireland - Totals PCDD/PCDF		
0.009 - 0.15 England		
Pre-1900, 0.30 - rural U.K. 1990's (Totals PCDD/PCDF)		
0.09-64 - EU		
0.78-17-Rural } 4.9 -87 - Urban } UK		
0.246-20-Rural Alaska		
0.05 -43- Australia		
<b>Calculated Risk</b>		
60 (cancer)		
<b>Standards</b>		
20 - MA		
90- Michigan		3,000 - UCL (MassDEP,2006)
10-Ontario		
1000- Japan		
3.9 -200 - US (2 EPA Regions, 9 States)		
<b>The Scale: ("cutoffs or thresholds")</b>		
Green	Yellow	Red
	50	1,000
Notes:		
1.) Controversial Dow Chemical Site, considerable internet traffic, other studies.		
2.) Note- TEQ's used by persons may vary		

Figure 3. Dioxin (Generally as 2,3,7,8 TCDD Equivalent)

Dioxin is less commonly analyzed for than other urban fill parameters, probably partly due to its high analytical cost per sample. Natural background sources of dioxin include brush and forest fires and volcanic eruptions, although the contribution from natural sources is relatively small compared

with anthropogenic sources (USEPA, 2006b). The greatest environmental source is from historical industrialization that occurred from the 1920s through the 1970s. Airborne releases from commercial and municipal waste incineration, the manufacture and use of herbicides, and the land application of wastewater treatment sludge from pulp and paper plants resulted in major environmental releases (USEPA, 2006b). While strict controls have dramatically reduced industrial sources, the chemical's slow breakdown has resulted in its common presence in urban fill material.

Dioxins are a complex mixture of chlorine-containing compounds with differing toxicities and are assessed following a toxic equivalency approach by assigning a toxicity factor relative to the most toxic form - 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). These numerical factors transform concentrations of dioxin compounds into equivalent concentrations of 2,3,7,8-TCDD (USEPA, 2004a).

MassDEP has not established a background number for 2,3,7,8-TCDD, but samples collected in Canton, Massachusetts, a number of years ago provided an average value of 60 ng/kg. The value of 60 ng/kg is also the 1E-05 residential risk-based direct contact value. This number was a useful guide but never officially adopted. Recent private/independent work for a site outside of Boston involving the evaluation of old incinerator ash blended in urban fill soil yielded results ranging from 0.86 to 80 ng/kg, with an average of 17 ng/kg based on a 44 sample data set. USEPA (Rodan, 1997) established value of 20 ng/kg (2,3,7,8-TCDD) equivalent background, which was recently adopted by MassDEP as the basis of the residential S-1 soil standard.

We suggest a value of 20 ng/kg or less as generally background, and any value more than 100 ng/kg indicates a potential site release specific situation.

No Significant (Potential) Risk	Probable (Potential) Risk	Certainty of (Potential) Risk									
<b>Background</b>											
100 (max.) - Natural- MA											
600 (max) - Coal/Wood Ash - MA ----->											
9 -39 (Ave. 19 - 239 samples) - Ohio Farm soils (Secondary References 2- 200 (Ave.10)											
17 - Natural - Washington State											
4-61 Rural } North Carolina 200-500 Urban }											
15-240 - Scotland											
8- Natural, 19-78 City Parks, 10-110 - Farms/Forest - Russia											
10-40 - Denmark											
51- NH											
<1.2 - 617 - NJ											
10-100 - NY											
17 - Washington State											
4 - (ave. 5,776 samples - extraction test) North Carolina											
23-36 Tennessee											
10-30 Alluvial Soils, Glacial Till & Drift, US											
3.3-148, most <20 - Oakland,CA											
40-350- Resuspended Road Dust											
<b>Calculated Risk</b>											
840 (HI @ 1)											
1,260 (HI@1.5)											
<b>Standards</b>											
300- MA		<b>Max's</b> 3,000 - UCL (MassDEP 2006)									
278- NJ		100 TCLP Threshold (USEPA)									
400-Denmark		250 -CA/T TCLP Threshold (MassDEP 2002)									
500-Residential } CT		5,000 - HUD - Permanent Solution									
1,000 -Industrial } ----->											
400/ } Bare soil - play area/yard - USEPA Program		Disposal: MA									
1,200 } (Lead Only)----->		1,000 Recycle, Unlined L.F's (Typ.)									
130 - Sediment Screening - MA		2,000 Lined Landfills (Lead based paint debris exempt from TCLP Criteria)									
<b>The Scale: ("cutoffs or thresholds")</b>											
<table border="1" style="width:100%; text-align:center;"> <tr> <td style="width:33%;"><b>Green</b></td> <td style="width:33%;"><b>Yellow</b></td> <td style="width:33%;"><b>Red</b></td> </tr> <tr> <td colspan="2"></td> <td>2,000</td> </tr> <tr> <td colspan="2">500</td> <td></td> </tr> </table>			<b>Green</b>	<b>Yellow</b>	<b>Red</b>			2,000	500		
<b>Green</b>	<b>Yellow</b>	<b>Red</b>									
		2,000									
500											

Figure 4. Lead

Lead has a high frequency of detection in urban fill soils. For example, lead was detected in 98 percent of the more than 300 samples collected to characterize various urban park sites in Boston. Lead is ubiquitous in urban fill soils due to its natural occurrence and anthropogenic sources, such as the historical use of leaded gasoline, leaded paint on building construction materials (including steel beams), and its presence in pipes and in solder.

Risk-based concentrations for lead are generally calculated based on noncarcinogenic health effects using the Integrated Exposure Uptake Biokinetic (IEUBK) Model based on an established blood level endpoint, as the USEPA has not established an oral reference dose (RfD) to calculated risks. MassDEP, however, has established an RfD to calculate lead risk as an alternative to using the model (MassDEP, 1992). Using this toxicity value, a residential risk-based value of 500 mg/kg is calculated based on direct contact. However, the actual residential soil standard is 300 mg/kg adopted from the land application of sludge regulations.

In general, concentrations considered to be at a No Significant Risk level are generally set in the 300 mg/kg to 500 mg/kg range. The Massachusetts residential standard for lead in soil is 300 mg/kg; the USEPA Region IX preliminary remediation goal (PRG) is 400 mg/kg (USEPA, 2004b); and the residential soil standard for Connecticut is 500 mg/kg. While natural background concentrations are generally 100 mg/kg or less and fall below the No Significant Risk level, MassDEP's background

concentration for fill soils containing coal or wood ash is 600 mg/kg. This value falls within the 500 mg/kg to 2,000 mg/kg Potential/Probable Risk range. Lead concentrations in the 500 mg/kg to 2,000 mg/kg range are generally acceptable for adult-only industrial use type exposure scenarios. The EPA Region IX Industrial PRG for lead is 800 mg/kg (USEPA, 2004b). Lead concentrations in urban fill typically fall within this range.

Upper bound limits of 3,000 mg/kg and 5,000 mg/kg have been established by MassDEP (MassDEP, 2006) and the Federal Department of Housing and Urban Development (HUD, 1995), respectively. At these concentrations, lead-contaminated soil must be removed, controlled, or contained.

<b>No Significant (Potential) Risk</b>	<b>Probable (Potential) Risk</b>	<b>Certainty of (Potential) Risk</b>
<b>Background</b>		
2-Natural-MA - also max. allowed	} "90th percentile"	
7- Coal/Wood Ash - MA - also max. allowed		
0.98 - 2.1 - Illinois - 95th percentile		
0.4 - Sweden		
0.1 - Denmark		
low - "negligible,"		
<1-1.3 -NY		
<b>Calculated Risk</b>		
7-8-Cancer, residential direct contact		
<b>Standards</b>		
0.7 - MassDEP (pre. 2006)		<b>UCL</b>
2 - MassDEP 2006 (4-S-2 soil, 30-S-3 soils - lower exposure potential)		300
0.66 - NJDEP PQL (04)		
1.0 - Denmark		
1- CT		
0.088-2.5 - Range, 14 States (Cluster 0.6-0.7, ave. 0.63)		
<b>The Scale: ("cutoffs or thresholds")</b>		
Green	Yellow	Red
	2	20

Figure 5. PAHs

PAHs as represented by benzo(a)pyrene, like metals, are ubiquitous in urban fill soils. Because PAHs are the product of incomplete combustion, they are detected in non-urban soils from fallout from forest fires and even volcanoes. They are particularly prominent in urban soils due to anthropogenic sources, such as gasoline and diesel exhaust, petroleum oils, and asphalt binders.

Benzo(a)pyrene is classified as a carcinogen (USEPA, 2006) and calculated, risk-based concentrations at No Significant Risk levels are often very low compared to concentrations of benzo(a)pyrene in fill soils. While the MassDEP 1 in 100,000-excess-lifetime-cancer-risk, risk-based residential direct contact standard for benzo(a)pyrene is 7.8 mg/kg, risk-based concentrations using USEPA guidance are an order of magnitude lower, due to different factors used in the calculations. The primary differences between these state and federal values are due to differences in dermal absorption factors and adherence factors and the omission of inhalation risks.

For example, residential risk-based PRGs calculated at a 1E-05 risk level from EPA Region III and Region IX are 0.87 mg/kg and 0.62 mg/kg, respectively (USEPA, 2006c) (USEPA, 2004b). Even PRGs calculated based on industrial exposures are relatively low with values of 3.9 mg/kg (Region III) and 2.1 mg/kg (Region IX) (USEPA, 2006c) (USEPA, 2004b). Since benzo(a)pyrene is considered mutagenic, these values may decrease further now that USEPA has issued guidance (USEPA, 2005a) for the assessment of mutagenic compounds that applies additional toxicity factors for the carcinogenic risk assessment of early life stages.

Given the very low risk-based values (less than detection limits in many cases), defining an appropriate background concentration for PAHs in fill is essential to achieve a condition of No Significant Risk. Therefore, it is essential to be able to distinguish between PAH concentrations attributable to background versus concentrations representative of a release. MassDEP evaluated several fill data sets, particularly the large 750 sample Central Artery/Tunnel project database and determined that the 7 mg/kg is an appropriate background concentration for benzo(a)pyrene in urban fill affected with coal and wood ash. In addition, 2 mg/kg was set as natural background and the residential standard was also recently adjusted accordingly to 2 mg/kg from 0.7 mg/kg based on background. Evaluating this data collectively, the No Significant Risk level is 2 mg/kg or less. The Potential/Probable Risk range is 2 mg/kg to 10 mg/kg, given the fill background value of 7 mg/kg. The upper bound value, is 300 mg/kg based solely on MassDEP's upper concentration limit (MassDEP, 2006).

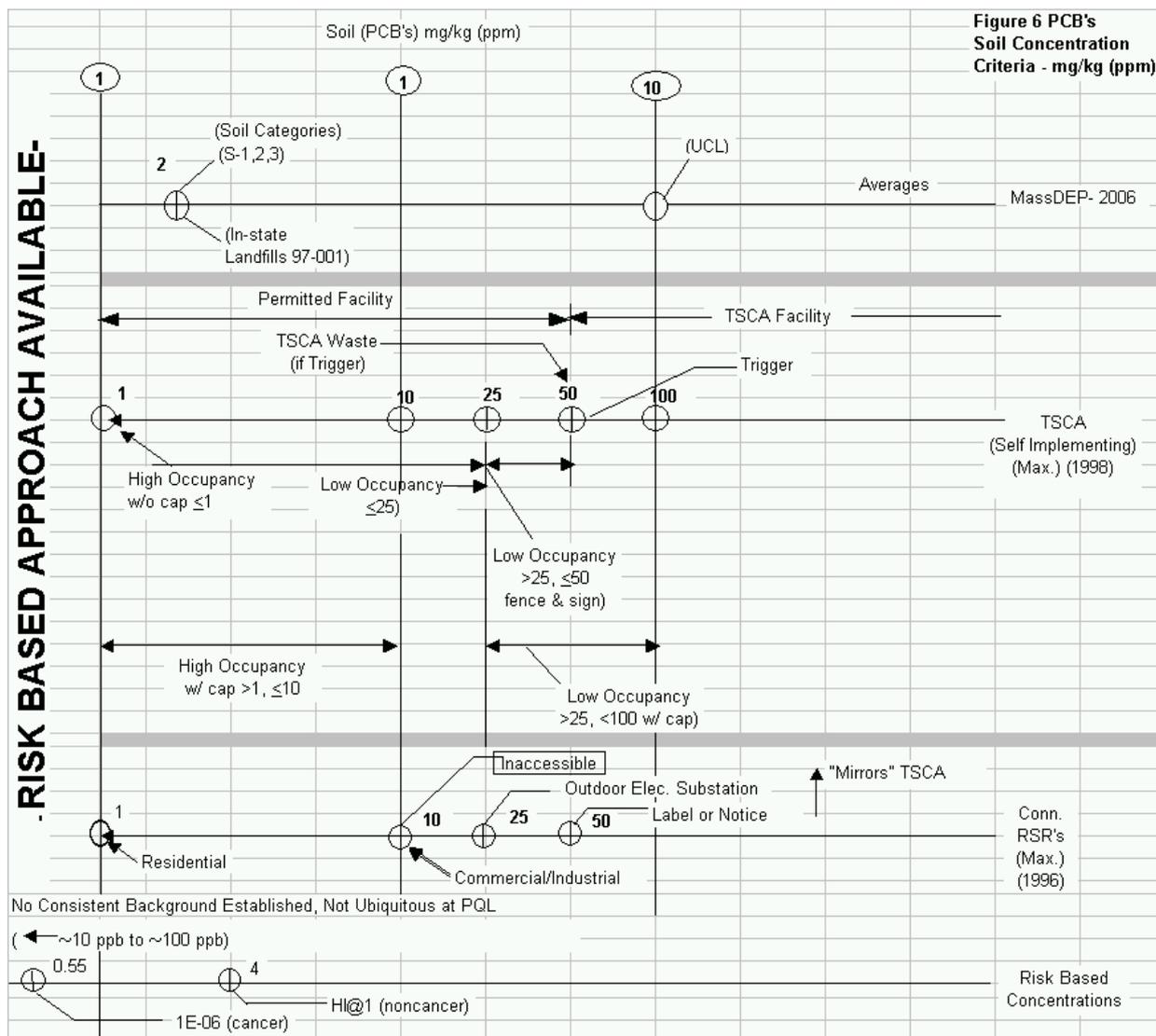


Figure 6. PCBs

For sites in industrialized areas with a history of PCB use, a determination of background levels is important due to the persistence and pervasiveness of PCBs. Concentrations ranging from 0.1 (1E-06 risk level) mg/kg to 1 mg/kg (1E-05 risk level) may be considered background (USEPA, 1990). However, because their presence may involve a multiple regulatory framework of both state regulators and USEPA under the Toxic Substances Control Act (TSCA), it was decided to provide a summary plot illustrating a range of values. This effort appears on Figure 6. The most important regulatory “trigger” is the 50 mg/kg TSCA limit. Its application depends on the date of release, but if one is doing remediation, any exceedance of the number means the activity is subject to TSCA and cleanup will be either 1 mg/kg maximum allowed of any point or a risk-based cleanup goal. (USEPA, 2005b) (Tisa, 2006)

The USEPA residential PRG of 1 mg/kg is based on very conservative exposure assumptions. For example, the ingestion rates for children and adults are two times greater than MassDEP ingestion rates; the inhalation pathway assumes that someone is on the site 24 hours per day for 30 years; and concentrations of PCBs in the air of a home will be the same as ambient air. Consequently, site specific, risk-based concentrations can be greater than 1 mg/kg. The MassDEP residential soil standard is 2 mg/kg (although adopted from land application of sludge regulations) and the calculated residential risk-based direct contact value is 5.5 mg/kg.

For industrial settings, the USEPA recognizes values ranging from 10 to 25 mg/kg as risk-based remedial goals (USEPA, 1990). At Superfund sites, these higher values are considered sufficiently protective for workers, since they are still within the acceptable range of 1E-04 using residential assumptions.

To put high end concentrations in perspective, the USEPA has guidelines for selecting remedial options based on whether PCB concentrations are considered either a principal threat or a low threat. It is expected that principal threats should be treated and includes soils with PCBs detected at greater than 100 mg/kg in residential locations and greater than 500 mg/kg in industrial locations. Consideration of containment should be given to low threat soils with concentrations 100 mg/kg or less. (USEPA, 1990)

## 6. CONCLUSIONS

<i>Constituents</i>	<i>Air (Esp. Indoor)</i>	<i>Soil as Addressed in this Document</i>
Benzene, other gasoline related organics	✓	–
Chlorinated organics	✓	–
<b>Metals (As/Pb)</b>	–	(✓)
<b>PAHs (Benzo(a)pyrene)</b>	–	(✓)
<b>Asbestos</b>	✓	(✓)
<b>Dioxin</b>	–	(✓)
<b>PCBs</b>	–	(✓)
Pesticides	–	–

Figure 7. Background Information Availability

1. Figure 7 summarizes all the constituents initially considered relative to urban background and a host of criteria. Gasoline-related hydrocarbons and chlorinated organics/degradation byproducts have background values for indoor air, but not for soil. This paper addressed the key metals arsenic and lead, PAHs by focus on benzo(a)pyrene, plus asbestos, dioxin, and PCBs, all related to soil. Pesticides were not addressed.
2. The authors reviewed the literature, examined available background criteria, displayed example standards, and computed current risk based numbers.
3. The authors selected two thresholds or concentration criteria. The first would cross from below standards, background, no significant risk, into a cautionary area of potential/probable risk. The second would cross onto a certainty of risk, a distinctly unacceptable situation requiring comprehensive action, potentially costly.
4. Finally, as illustrated at the bottom of Figures 1 through 6, the authors have provided a scale or key allowing the user to make an initial screening of site-specific data. Detailed or final analysis, however, must be accomplished by a professional risk assessor.

## REFERENCES

- AEAT (AEA Technology). 1999. Compilation of EU Dioxin Exposure and Health Data, AEA Technology, Oxfordshire, England, OX 11 0QJ. 1999.
- AEHS (The Association for Environmental Health and Sciences). 2003. State Summary of Cleanup Standards. The Association for Environmental Health and Sciences, Amherst, MA 01002. 2003.
- Allsopp, M., 1994. Achieving Zero Dioxin, An Emergency Strategy for Dioxin Elimination. Greenpeace Communications, London. EC1R3DB. Sept. 1994.

- ATSDR (Agency Toxic Substances and Disease Registry). 1993. Public Health Assessment, Ramapo Landfill, Ramapo, Rockland County, New York. Appendices. Prepared by: New York State Department of Health, Albany, New York 12237, December 1993. <http://www.atsdr.cdc.gov/HAC/PHA/ramapo/r/f-p4.html>
- ATSDR (Agency for Toxic Substances and Disease Registry). 1997. Dioxin and Dioxin-Like Compounds in Soil, Part 1: ATSDR Interim Policy Guideline, Toxicology and Industrial Health, Vol. 13, No. 6. pp. 759-768, 1997. (Policy Effective date August 1997) <http://www.atsdr.cdc.gov/dioxindt.html>
- ATSDR (Agency for Toxic Substances and Disease Registry). 2001. Public Health Statement for Asbestos, Summary Chapter from: Toxicological Profile for Asbestos, Agency for Toxic Substances and Disease Registry, Department of Health and Human Services, Public Health Service. Atlanta, GA. 2001. <http://www.atsdr.cdc.gov/toxprofiles/ph61.html>
- ATSDR (Agency for Toxic Substances and Disease Registry). 2002. Public Health Assessment. Central Wood Preserving Company. Slaughter, East Feliciana Parish, Louisiana. Appendices. Prepared by Louisiana Department of Health and Hospitals, September 2002. [http://www.atsdr.cdc.gov/HAC/PHA/central\\_wood/cwp\\_p.2.html](http://www.atsdr.cdc.gov/HAC/PHA/central_wood/cwp_p.2.html)
- Baldwin, L. and McCreary, H. 1998. Study of State Soil Arsenic Regulations. Association for the Environmental Health of Soils, Amherst, MA 01002. December 1998.
- CDM 1991. Final Report/Subtask #8.2, Environmental Consequences of Utilizing Boston Blue Clay In Landfill Closure, Massachusetts Department of Public Works, Boston, MA 02110. Final Report, January 1991.
- City Farmer, 2003. Urban Agricultural Notes. Heavy Metal Concentrations in Urban And Peri-Urban Gardens of Dzerzhinsk and Nizhny Novgorod, Russia. Published by City Farmer, Canada's Office of Urban Agriculture. December 2003. [cityfarm@intercharge.ubc.ca](mailto:cityfarm@intercharge.ubc.ca), <http://www.cityfarmer.org/russianmetal.html>
- City of Oakland, 2005. City of Oakland, Survey of Background Metal Concentration Studies, Oakland Urban Land Redevelopment Program, Oakland, CA 94612. December 2005.
- CTDEP (Connecticut Department of Environmental Protection) 1996. State of Connecticut. Regulation of Department of Environmental Protection concerning Remediation Standard ( and related Guidance Documents) Hartford, Connecticut 06106-5127, January 1996.
- Danish Environmental Protecting Agency, 2002. Guidelines on Remediation of Contaminated Sites. Environmental Guidelines No. 7, 2002. (Only available online in English) [www.mst.dk/udgiv/publications/2002/87-7972-280-6/html/default.eng.htm](http://www.mst.dk/udgiv/publications/2002/87-7972-280-6/html/default.eng.htm)
- Department of Ecology. 1994. Natural Background Soil Metals Concentrations in Washington State. Publication #94-115. Executive Summary. Department of Ecology, Olympia, WA 98504-7600, October 1994.
- DEH (Department of the Environment and Heritage). 2004. Dioxins in soil in Australia, Technical Report No. 5, Department of the Environment and Heritage, Parkes ACT 2600 Australia. ISBN0642 S49974. May 2004.
- DEQ (Department of Environmental Quality). 1999. Michigan Soil Background Dioxin Data, Sample Locations and Results as of November 1999. Department of Environmental Quality, Lansing, Michigan 48909-7973. November 1999.
- DEQ (Department of Environmental Quality). 2004. Dioxin Contamination in the Midland Area. Department of Environmental Quality, Lansing, Michigan 48909-7973. July 2004.
- DNREC (Department of Natural Resources and Environmental Control). 2005. Arsenic References, Cleanup of Arsenic – Contaminated Sites, Dover, DE 19901. August, 2005. <http://www.dn.rec.state.de.us/dnrec2000/Divisions/AWM/SIRB/Arsenic/index.htm>
- Dow (Dow Chemical). 2006. What is the 90 ppt Standard? Listed Under Regulatory Activities, 2006. <http://www.dow.com/facilities/numerical/michigan/dioxin/regulat/standards.htm>.
- European Commission. 2004. Dioxin & PCBs: Environmental Levels and Human Exposure in Candidate Countries, Summary Report. European Commission, Brussels. June 2004.
- Fleischer, Philip, RE: Background Dioxin Levels?, August 1997 <http://lists.essential.org/1997/dioxin-l/msg00324.html>
- Folkes, D.J., and Keuhster, T.E. 2001. Contributions of Pesticide use to Urban Background of Arsenic in Denver, Colorado, U.S.A. Environmental Forensics. 2, 127-139. April 2001.
- HUD (The U.S. Department of Housing and Urban Development). 1995. Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing. June 1995.
- Illinois EPA (undated). Urban Area Polycyclic Aromatic Hydrocarbons Study Tiered Approach to Corrective Action Objectives. Tabulation Background Carcinogenic PAH 95th Percentile Concentrations (mg/kg) Springfield, Illinois 62702
- MassDEP (Massachusetts Department of Environmental Protection) 1992. Documentation for the Risk Assessment Shortform Residential Scenario. Office of Research and Standards and the Bureau of Waste Site Cleanup. Policy #WSC/ORS-142-92. October 1992.
- MassDEP (Massachusetts Department of Environmental Protection) 1997. Reuse and Disposal of Contaminated Soil at Massachusetts Landfills, Policy #COMM97-001. Department of Environmental Protection, Boston, Massachusetts 02108. August 1997.
- MassDEP (Massachusetts Department of Environmental Protection) 2002. Technical Update, Background Levels of Polycyclic Aromatic Hydrocarbons and Metals in Soil. Department of Environmental Protection, Boston, MA 02108-4746. May 2002.
- MassDEP (Massachusetts Department of Environmental Protection) 2006. Massachusetts Contingency Plan, 310 CMR 40.0000, (and related Guidance Documents) Massachusetts Department of Environmental Protection, Boston, Massachusetts 02108. April 2006.

- MCES (Metropolitan Council Environmental Services) 2004. A Survey of Regulations Used to Control the Use and Disposal of Stormwater Pond Sediments in the United States and Canada, Metropolitan Council Environmental Services, EQA, Saint Paul, MN 55101, Report 04-542. November 2004.
- Midland Health Watch, Facts on soil standards. [http://www.midlandhealthwatch.com/facts\\_on\\_soil\\_standards.htm](http://www.midlandhealthwatch.com/facts_on_soil_standards.htm)
- Natural Background Soil Metals Concentrations in Washington State, Publication #94-115, October 1994
- NJDEP (New Jersey Department of Environmental Protection and Energy). 1993. A Summary of Selected Soil Constituents and Contaminants at Background Locations in New Jersey. New Jersey Department of Environmental Protection and Energy, Site Remediation Program, Trenton, New Jersey. September 1993.
- NHDES (New Hampshire Department of Environmental Services), 2001. Table 1. Revised Background Concentrations of Metals in Soil. NHDES Risk Characterization and Management Policy (Subsection 1.5(4)(c)). (Revised) Concord, NH 03302-0095. April 3, 2001.
- NYSDEC (New York State Department of Environmental Conservation). 1994. Heavy Metals Soil Cleanup Criteria. Table 4 Recommended soil cleanup objectives (mg/kg or ppm) Heavy Metals. Division of Environmental Remediation. TAGM#4046. January 1994. <http://www.dec.state.ny.us/website/der/tagms/prtg4046e.html>
- NCDA & CS (North Carolina Department of Agriculture & Consumer Services) 2006. Heavy Metals in North Carolina Soils, Occurrence and Significance. North Carolina Department of Agriculture & Consumer Services, Agronomic Division, Raleigh, NC. Last Updated February 2006. <http://www.ncagr.com/agronomi/hflyer.htm>
- Ohio State University. 2001. Background Levels of Heavy Metals in Ohio Farm Soils, Research Circular 275-83. Columbus, Ohio 43210. July 2001. <http://ohioline.osn.edu/re275/re275-3.html>
- Ontario, 2004. Soil, Groundwater and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act Queen's Printer for Ontario. March 2004.
- Pattle Delaware Partners LTD. 2002. Dioxin Concentrations in Residential Soil, Paritu, New Plymouth. Ministry for the Environmental, New Zealand. September, 2002. <http://www.mfe.govt.nz/publications/hazardous/taranaki-dioxin-report-sep02/index.html>
- RAIS (The Risk Assessment Information System) 2006. The Risk Assessment Information System, USDOE, Oak Ridge Operations Office, TN 37830 Last Updated: April 27, 2006. <http://risk.lsd.ornl.gov/cgi-bin/background/generic>
- R&H Hall. Technical Bulletins. 1999. Dioxins/PCB's and the Food Chain-A Review. R&H Hall, Dublin 8, Ireland. 1999. [http://www.rhall.ie/bulletins/diox\\_4.htm](http://www.rhall.ie/bulletins/diox_4.htm)
- Rocky Mountain Center for Occupational and Environmental Health. 1999. A Comparison of Dioxin Levels, Found in Residential Soils of Davis County, Utah with those found in Residential Soils in the Denver Front Range, Department of Family and Preventative Medicine, University of Utah. 1999.
- Rodan, B.D., 1997. Polychlorinated Dioxins and Furans: Sources, Emissions, and Levels. National Center for Environmental Assessment, Office of Research and Development, U.S., Environmental Protection Agency, Washington, DC 20460. Presented at UNEP Regional Awareness Raising Workshop on POP's, Bangkok, Thailand, November 1997.
- Rutgers Cooperative Research & Extension. 2003. Lead Contaminated Soil: Minimizing Health Risks, Rutgers Cooperative Research and Extension, The State University of New Jersey, New Brunswick, August 2003.
- Schaner, J.J., Lough, G.C., Shafer, M.M., Christensen, W., et.al. 2006. Characterization of Metals Emitted from Motor Vehicles. The Health Effects Institute, Report 133, Charlestown Navy Yard, Boston, MA 02129. April 2006
- Smith, A.H., Lopipero P., 2001. Evaluation of the Toxicity of Dioxins and Dioxin-like PCBs: A Health Risk Appraisal for the New Zealand Population. Ministry for the Environment, Wellington. ISBN 0-478-09091-9. February 2001.
- The Macaulay Land Use Research Institute. 2005. Trends in Pollution of Scottish Soils, Transects – 1990. Aberdeen, AB158QH UK 2005. <http://www.macaulay.ac.uk/tipss/lead/htm>
- Tisa, K., 2006. The TSCA PCB Regulations Post-1998. Powerpoint Presentation to the Licensed Site Professional Association, United States Environmental Protection Agency, Boston, MA. 2006.
- Tucker, M.R., Hardy, D.H., Stokes. C.E. 2005: Heavy Metals in North Carolina Soils: Occurrence and Significance. North Carolina Department of Agriculture and Consumer Services, Agronomic Division, Raleigh, North Carolina, Revised October 2005.
- USEPA (U.S. Environmental Protection Agency). 1990. Guidance on Remedial Actions for Superfund Sites with PCB Contamination. Office of Emergency and Remedial Response. EPA/540/G-90/007. August 1990.
- USEPA (U.S. Environmental Protection Agency). 2004a. Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-*p*-Dioxin (TCDD) and Related Compounds National Academy Sciences (NAS) Review Draft. October 2004.
- USEPA (U.S. Environmental Protection Agency). 2004b. Region 9 Preliminary Remediation Goals 2004 Table. <http://www.epa.gov/region9/waste/sfund/prg/index.html>
- USEPA (U.S. Environmental Protection Agency). 2005a. Supplemental Guidance for Assessing Susceptibility from Early Life Exposures to Carcinogens. EPA/630/R-03/003F. March.
- USEPA (U.S. Environmental Protection Agency). 2005b. Polychlorinated Biphenyl (PCB) Site Revitalization Guidance Under the Toxic Substances Control Act (TSCA), OPPT -2004-0123, November 2005.
- USEPA (U.S. Environmental Protection Agency). 2006a. Integrated Risk Information System (IRIS). Online toxicity database. Office of Research and Development, National Center for Environmental Assessment. Last updated on Wednesday, March 8th, 2006. URL: <http://www.epa.gov/iris/>

- USEPA (U.S. Environmental Protection Agency). 2006b. Dioxin: Frequently Asked Questions (FAQs). National Center for Environmental Assessment.
- USEPA (U.S. Environmental Protection Agency). 2006c. Region III Risk-Based Concentration Table. Updated April 2006. <http://www.epa.gov/reg3hwmd/risk/human/index.htm>.
- Visher, J., 1999. Japan's New Dioxin Standards, From the Mainichi: Shimban, November 5, 1999. <http://lists.essential.org/dioxin-1/thrd14.html>