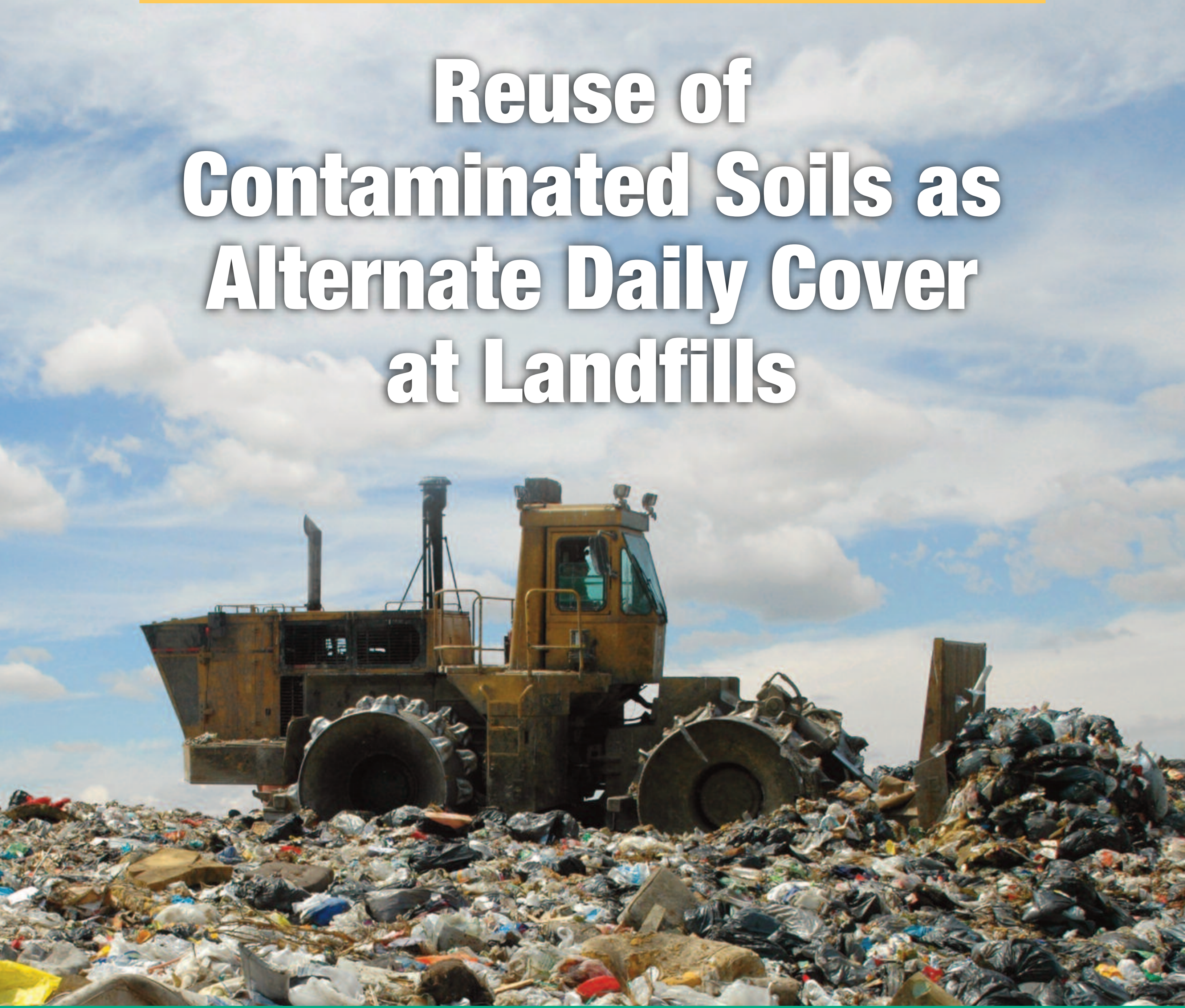
Reuse of Contaminated Soils as Alternate Daily Cover at Landfills



A Risk to Workers?

A primer on techniques for assessing the potential health risks to U.S. landfill workers using methods developed under the Superfund program.

Beneficial reuse of waste materials at landfills is practiced in numerous states across the United States. Landfill regulations require the covering of disposed municipal solid waste (MSW), both on a temporary basis as daily covering of newly deposited wastes and on a long-term basis through landfill capping and closure. Consequently, landfill operations typically require an abundant supply of cover material. The traditional alternatives include clean soils, foams, and tarps, all of which represent costs to landfill operators and utilization of potentially valuable materials that could be used in landscaping and other applications. Substituting waste materials as cover provides the benefit of displacing a needed commodity—cover soil—with a material that would otherwise be disposed of as a waste material.

Table 1 provides a summary list of waste materials that are known to have been approved for beneficial reuse at landfills (typically as daily cover material). These and other materials can be accepted at MSW landfills if they pass the categorical tests used by the U.S. Environmental Protection Agency (EPA) for determining hazardous wastes (i.e., ignitability, corrosivity, reactivity, toxicity, and "listed" wastes), as set out under the Resource Conservation and Recovery Act (RCRA). But in theory, the wastes can still contain high levels of contaminants, so long as the RCRA characteristic tests are satisfied.

Contaminated soils represent a category of waste that is a frequent candidate for beneficial reuse at landfills. According to an EPA-funded project on material reuse, at least 15 states have made determinations that allow for beneficial use of contaminated soils at landfills (see Table 2). Sending contaminated soils to landfills has long been a management strategy in hazardous waste site remediation work, as disposal in a landfill eliminates potential exposure pathways through which the general public might contact the soils. If the purpose of sending the soils to the landfill is to prevent people from contacting contaminants, are there potential risks to the workers at landfills who are applying these soils for beneficial reuse as daily cover?

Analyzing Risk

There are potential considerations of regulatory jurisdictions in addressing this question. Determinations of the need to landfill contaminated soils are frequently dictated by state or federal programs designed to regulate contaminants in soil at hazardous waste disposal sites (rather than at MSW landfills). In this context, the term "hazardous" typically pertains to public health protection as rooted in EPA's Superfund program, which philosophically is designed to protect individuals from any significant health risks. Landfill owners, like all employers, are subject to the requirements of the Occupational Safety and Health Administration (OSHA), which has specific requirements for protecting workers from excessive exposure to chemical contaminants. Arguably, landfill workers are subject to a variety of different job hazards, some of which may be more significant (in terms of risk) than potential contact with contaminated soils.

Discussion of the applicability of contaminated (hazardous) site program regulations to MSW landfill workers involves policy considerations beyond the scope of this article. However, it is worth considering the potential implications of applying risk-based hazardous waste site regulations to landfill workers (or any other category of workers subject to OSHA requirements). To do so, consider a simplistic example comparison of risk-based concentrations of contaminants in the air at a landfill. Table 3 compares the OSHA Permissible Exposure Levels (PELs) to the EPA's Regional Screening Levels (RSLs) for industrial air, which are risk-based. The values differ by several orders of magnitude, reflecting the greater degree of protection afforded by EPA risk assessment methodologies.

Table 1. Materials approved for beneficial reuse at landfills in 1 or more states.

Auto Shredder Residue	Foundry Sand—Green Sand
Circulating Fluidized Bed Ash	Glass
Coal Bottom Ash	Gypsum Wallboard
Coal Fly Ash	Slag—Foundries
Construction and Demolition Debris	Slag—Steel
Contaminated Soil	Stormwater Sediments
Dredge Material	Street Sweepings
Drinking Water Treatment Sludge—Aluminum	Waste Tires
Drinking Water Treatment Sludge—Ferric	Waste-to-Energy Ash
Drinking Water Treatment Sludge—Lime	Wastewater Treatment Plant Filter Sand
Flue Gas Desulfurization Sludge	Wood Ash
Foundry Sand	

Source: http://www.envcap.org/statetools/brsl/.

Table 2. States that allow the reuse of contaminated soils at landfills.

Florida	New York
Hawaii	North Carolina
Iowa	North Dakota
Kentucky	South Dakota
Maryland	Texas
Massachusetts	Virginia
Michigan	Wyoming
Mississippi	

Source: http://www.envcap.org/statetools/brsl/.

Calculating Potential Exposure

Notwithstanding the above discussion of regulatory authority, and making the assumption that it is appropriate to use EPA risk assessment methods to establish acceptable risk-based levels of contaminants in soils that can be handled by landfill workers, how specifically should the levels be established? Application of risk assessment methods entails myriad assumptions about how workers come in contact with soils and the degree and intensity of exposure. For simplicity, one might initially select "off the shelf" risk-based screening concentrations that have been derived using standard default assumptions and protective risk-based target levels. Alternatively, one might attempt to apply risk assessment equations tailored to the activities that landfill workers engage in when managing and applying cover soils.

In either case, it is important to consider the basics of risk assessment methods. The first step entails the identification of plausible pathways whereby individuals might contact contaminants. Typically, workers are assumed to contact contaminants in soil via three pathways:

- Incidental ingestion, frequently associated with hand-to-mouth contact;
- Dermal contact, whereby contaminants are absorbed from soil adhering to skin; and
- Inhalation of soil suspended in the air as dust.

Generically, potential exposure to a contaminant via the ingestion and dermal pathways is calculated in the form of dose, which is essentially the amount of a contaminant contacted per body weight. In equation form:

$$\text{Dose} = (\text{Concentration in Soil} \times \text{Contact Rate} \times \text{Exposure Frequency/Duration}) / (\text{Body Weight} \times \text{Averaging Time})$$

The contact rate assumes different forms. For incidental ingestion, it simply is the daily rate that soil is swallowed. For dermal contact, it depends on both the level of soil adhered to skin and the fraction of the contaminant absorbed from it.

Note that potential exposure and risk via dust inhalation is calculated differently to match conventions developed for toxicity data. For inhalation, potential exposure is estimated as the average concentration of the contaminant in air inhaled over time, and unit risk factors and reference concentrations that characterize inhalation toxicity data are expressed in terms of concentration units.

Given exposure estimates for these pathways, potential risks to health are evaluated for two broad categories. Incremental Cancer Risk (ICR) is estimated for contaminants known or suspected to cause cancer in humans. For each potential carcinogen, risk is calculated as the product of the lifetime average daily dose and the contaminant-specific cancer slope factor, or potency, which is an estimate of chemical's capacity to initiate or promote cancer:

$$\text{Incremental Cancer Risk (ICR)} = \text{Lifetime Average Daily Dose} \times \text{Potency}$$

Table 3. A comparison of EPA Regional Screening Levels (RSLs) and OSHA Permissible Exposure Limits (PELs).

Chemical	OSHA PEL (µg/m^3)	EPA RSL for Industrial Air (µg/m^3)
Arsenic	10	0.0029
Chromium VI	5	0.00015
Lead	50	0.15

The chance for adverse health effects other than cancer is characterized through the calculation of a Hazard Quotient (HQ), expressed for ingestion and dermal exposure pathways as the ratio of the average daily dose divided by the chemical-specific reference dose, which is derived from toxicological studies to correspond to exposure levels that can be tolerated with no significant chance of adverse health effects:

Noncancer Hazard Quotient =
Average Daily Dose / Reference Dose

Risk assessment equations can be rearranged to calculate permissible risk-based concentrations of contaminants in soil for given target risk levels and exposure assumptions. Common target risk levels are ICRs of 1 per million and 10 per million, and HQs of 0.1 and 1. Exposure parameters are typically selected based upon professional judgment to estimate likely degrees of exposure, such as reasonable maximum or central tendency estimates. Variability and uncertainty are inherent to each parameter, and as a means of encouraging uniformity, adoption of consensus-based standard default values has evolved over time.

Risk Assessment

Two examples of consensus-based approaches to risk assessment that explicitly examine worker exposure to soil are the Massachusetts Department of Environmental Protection's Shortform risk assessment spreadsheets (construction worker scenario) and EPA's Regional Screening Level (RSL) calculator (composite worker scenario). Table 4 provides risk-based concentrations in soil that meet highly protective and moderately protective target risk criteria using these two approaches, by employing the default exposure assumptions built into each program. The lower of the two values for the ICR and HQ calculations is presented as the risk limiting value, with values based on ICR italicized. Within each program, values differ by a factor of 10 simply based on the same order of magnitude difference between the highly and moderately protective target risk criteria. Between the programs, however, risk-based values can differ substantially. Reasons for these differences vary among chemicals, but generically include:

- Choices of toxicity values, for example, whether ethylbenzene is treated as a carcinogen, or whether a reference dose is considered for lead;
- Critical exposure parameters such as the duration of exposure, which for the EPA composite worker is 25 years, but only 6 months for the Massachusetts construction worker; and
- Other differences in exposure assumptions and contaminant-specific parameters.

Table 4. Risk-based concentrations in soils estimated for worker protection (mg/kg).[1]

Contaminant	Highly Protective[2] ICR=1e-6, HQ=0.1		Moderately Protective[2] ICR=1e-5, HQ=1		Background	
	MADEP Shortform[3]	EPA RSL	MADEP Shortform[3]	EPA RSL	Natural	Urban fill
Arsenic	19	*3.0*	190	*30*	20	20
Benzene	600	*5.1*	6,000	*51*	n/a	n/a
Benzo(a)pyrene	*30*	*2.1*	300	*21*	2	7
Beryllium	42	*230*	420	*2,300*	0.4	0.9
Chromium (VI)[4]	*310*	*6.3*	*3,100*	*63*	30	40
Ethylbenzene	3,100	*25*	31,000	*250*	n/a	n/a
Lead[5]	100	n/a	1,000	n/a	100	600
Naphthalene	4,900	*17*	49,000	*170*	0.5	1
Toluene	49,000	4,700	490,000	47,000	n/a	n/a
Xylenes	24,000	250	240,000	2,500	n/a	n/a
Zinc	2,900	35,000	29,000	350,000	100	300

Notes:
[1] All concentrations in mg/kg.
[2] Italicized risk-based concentrations based on incremental cancer risk (ICR); otherwise the basis is the non-cancer hazard quotient (HQ).
[3] Background levels have been published by the MA Department of Environmental Protection and represent upper percentile levels typically found in soils.
[4] Background levels for chromium are not distinguished by valency. In most soils, chromium is present predominantly in the trivalent state (see the ATSDR toxicological profile for chromium, https://www.atsdr.cdc.gov/toxprofiles/tp7-c6.pdf), but the hexavalent fraction can be substantial in certain industrial wastes.

Insights from these two example approaches include:

- The importance of choices on exposure parameters and chemical toxicity values, which despite many years of effort to move toward consensus-based values, can still reflect programmatic and regional differences; and
- Some of the estimated risk-based concentrations are comparable to or lower than typical background levels found in uncontaminated soil (examples of which are included in Table 4; e.g., arsenic and benzo(a)pyrene). That is, the worker risk from handling contaminated soils may be no greater than if handling common soil.

Summary

In summary, contaminated soils are used as daily cover material at solid waste landfills nationally. While this is an important beneficial use of such contaminated materials, there are potential risks to the workers at landfills who are working with these soils. The protective nature of risk assessment methods and assumptions can lead to low limits on the concentrations of certain contaminants. Care should be taken to evaluate whether "off the shelf" risk-based concentrations for workers, such as EPA RSLs, are appropriate to apply directly to landfill workers. It may be desirable to modify default exposure assumptions to specifically consider how soils are handled and managed by workers, both in terms of frequency of contact, amounts typically contacted, and duration of exposure.

For example, if cover soils at a landfill are typically applied at the end of day, workers spend only a fraction of their time handling these soils relative to other tasks. In that case, the levels of assumed soil contact could be reduced/pro-rated to the fraction of time contaminated soils are handled during the workday. Also, to reconcile potential philosophical conflicts with OSHA regulations, target risk criteria could be raised to allow for a lessened, but still reasonable level of protection compared with public health-based criteria. For example, risk-based levels for workers could be derived based on the 100 per million upper limit of the Superfund incremental cancer risk range, and target hazard quotients could be raised above 1 in cases in which reference doses embody large safety factors. **em**

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