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Chapter 9

ARSENIC CLEANUP CRITERIA FOR SOILS IN THE US AND ABROAD: COMPARING GUIDELINES AND UNDERSTANDING INCONSISTENCIES

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ABSTRACT

Widely divergent cleanup targets, guidelines and standards for arsenic in soils have been established by many regulatory, scientific and advisory organizations in the past 25 years, both in the United States and in other countries. In contrast to many other substances, for which guidelines and standards are similar or identical among agencies, arsenic has provided a powerful study in just how many different ways a single issue can be viewed. This paper provides a detailed survey concerning the breadth of arsenic soil criteria that have been proposed and applied, and explores the basic differences in their derivation, which can be based upon toxicological properties, geological background levels, anthropogenic background contributions, and practical site-specific considerations. A broad comparison of extant values in common use for USEPA, individual states, and non-US entities will be presented, coupled with a discussion regarding common examples of the technical bases for arsenic soil cleanup guideline development. Arsenic target levels in many cases can dominate remedial considerations at sites where the applicable criteria are very stringent. Several case studies will be presented to illustrate the problems that are inherent in such variable criteria for this ubiquitous and extraordinarily common substance.

Keywords: Arsenic, soil, cleanup guidelines, criteria, risk, variability

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1. INTRODUCTION

Over the past few decades, arsenic has been increasingly examined and analyzed due to its toxicological properties, broad aspects of exposure potential, and historically inconsistent cleanup targets and guidelines. Arsenic is a metalloid found naturally at high concentrations in some soils that can not be destroyed by the environment; however, it can change form (e.g., organic to inorganic, altered valence states) or become attached to or separated from particles. Arsenic is a known human carcinogen at sufficient levels in water and air, but credible reports of soil-based health effects are quite limited. There are a variety of soil cleanup guidelines from the U.S. Environmental Protection Agency (USEPA), state agencies, and international agencies. The guidelines vary across about a 1000-fold range (0.039 to 40 mg/kg) in the U.S. alone. In this summary report, we present many of these guidelines, and explore the various foundations and supporting information on which the guidelines are predicated.

2. REVIEW OF ARSENIC SOIL CRITERIA IN THE U.S. AND ABROAD

2.1 United States

The USEPA Regional Screening Level (RSL) for soil arsenic under unrestricted use (e.g., residential) assumptions is 0.39 mg/kg (USEPA, 2009). This level is based on a target cancer risk of 1E-06, toxicological guidance values from the Integrated Risk Information System (IRIS), and standard assumptions for exposure assessment and risk assessment. As shown on Table 1, many of the individual state guidelines for residential soil are taken directly from, or calculated very similarly to, the USEPA RSL. However, some states use an alternative cancer risk level and/or different exposure assumptions, and many states take into consideration the presence of arsenic at significant concentrations in naturally occurring background soils. Section 3 presents details on the various derivations of selected guidelines that are presented in Table 1.

2.2 International

The international guidelines that were reviewed provide considerable grounds for additional in-depth research. As with the US guidelines, the international levels have diverse, and often unexplained, foundations, which result in widely varying concentrations. In general, however, the international guidelines are consistently higher than the US numbers (5 mg/kg to 150 mg/kg for the selected countries that were reviewed; see Table 2).

3. ARSENIC SOIL CRITERIA: BASES & ASSUMPTIONS

3.1 Health Basis

The USEPA (2009) Regional Screening Levels (RSLs), as well as many state guidelines, are based on typical human exposure assessment assumptions (350 days/yr, 30 yr residence during a 70-yr lifetime, 100% relative bioavailability) and standard toxicological guidance values. The cancer target risk ranges from 1E-07 to 1E-04. At least 14 states (see Table 1) employ the USEPA RSL methodology and a 1E-06 cancer risk level, resulting in default guidelines that fall tightly between 0.38 mg/kg and 0.41 mg/kg. As noted later, that range is less than commonly encountered background soil arsenic levels in much of the country.

Whereas a systemic, or noncarcinogenic effects guideline typically is calculated as part of the process, it almost always is deferred based on using the lower of noncarcinogenic versus carcinogenic values. The exception is Texas, which uses a cancer risk level of 1E-04, resulting in a guideline of 34 mg/kg. The calculated noncancer guideline is 24 mg/kg, which thus becomes the state default Tier 1 Protective Concentration Level for residential exposure circumstances (TCEQ, 2009).

Recent information suggests that ongoing reassessment efforts by USEPA may further restrict the oral Cancer Slope Factor by as much as 15-20x, based on bladder and lung cancer studies. It should be noted that internal and external technical reviewers have rightly questioned such a dramatic reduction, noting that if those assumptions were correct we should be seeing an epidemic of bladder and lung cancer in the U.S., given that current drinking water guidelines are, and have been for decades, well above the new proposals in terms of ingested dose. The same can be said for the many countries outside the U.S. that have arsenic guidelines in drinking water and in soil that permit intakes that are considerably higher than the calculated health-based soil levels.

3.2 Ambient Background Basis

Many states use naturally occurring background soil arsenic levels as their default screening guidance. While these typically rely on geologic conditions, some jurisdictions also consider the possibility of historical anthropogenic contributions. The background concentrations found and reported herein range from 7 to 40 mg/kg. For Rhode Island, 7 mg/kg is the default guideline, based on

Table 1. Selected state cleanup guidelines for arsenic in soil for residential/unrestricted use.

State	**Guideline (*mg/kg*)**	**Basis**
Wisconsin (WDNR, 2009)	0.039	Cancer (10^{-7} risk level), standard risk assessment assumptions and toxicological guidance values
California (CalEPA, 2005)	0.07	Cancer (10^{-6} risk level), 4% dermal absorption assumption, CalOEHHA Slope Factors
AL (ADEM, 2008), CO (CDPH, 2007), DE (DNREC, 2007), ID (IDEQ, 2004), LA (LDEQ, 2003), MD (MDE, 2008), MS (MSDEQ, 2002), NC (NCDENR, 2005), OK (OKDEQ, 2007), OR (ODEQ, 2005), VA (VDEQ, 2009), WV (WVDEP, 2009), WY (WDEQ, 2009)	0.38 to 0.41	Cancer (10^{-6} risk level), either direct cite to EPA, or state-specific calculation with standard risk assessment assumptions and toxicological guidance values
Maine (MDEP, 2009)	1.4	Cancer (10^{-5} risk level), CalOEHHA Slope Factors
Florida (FDEP, 2005)	2.1	Cancer (10^{-6} risk level), 33% oral bioavailability, state-specific exposure assumptions
New Mexico (NMED, 2009)	3.59	Cancer (10^{-5} risk level), standard risk assessment assumptions and toxicological guidance values
Indiana (IDEM, 2009)	3.9	Noncancer soil-plant-human uptake (based on USEPA soil screening guidance)
Ohio (OEPA, 2008)	6.7	Cancer (10^{-5} risk level), 3% dermal absorption assumption
AZ (ADEQ, 2002), IA (IDNR, 2004), KS (KDHE, 2007), KY (KEEC, 2004), MA (CMR, 2003), MN (MDEQ, 2005), MO (MRBCA, 2006), NH (NHDES, 2007), NJ (NJAC, 2008), NY (NYSDEC, 2006), PA (PDEP, 2001), RI (RIDEM, 1996), WA (WAC, 2007)	7 to 40	State-specific Natural Background
Texas (TCEQ, 2009)	24	Noncancer (lower than cancer endpoint at 10^{-4} risk; 34 mg/kg)

Table 2. Selected international cleanup guidelines for arsenic in soil for residential/unrestricted use.

Country	Guideline *(mg/kg)*	Basis
Finland (FME, 2007)	5	Threshold value based on background and groundwater protection; lower and upper guidance values for ecological endpoints are 50 and 100 mg/kg, respectively; human health-based values were less restrictive
Canada (CCME, 2007)	12	Soil Quality Guideline - lower of the human health SQG or eco SQG
UK (England, Northern Ireland, Wales; UKEA, 2009)	32	Derived from UK oral Index Dose for drinking water, based on oral and dermal exposure of a young child
Netherlands (NEAA, 2008)	76	Soil Intervention Value indicating severe contamination condition – based on 10^{-4} risk level
Australia (ANEPC, 1999)	100	Health-based Investigation Level based on protection of a 2.5 year old child exposed to 100 mg soil/day via oral, dermal and inhalation routes
Japan (JME, 2003)	150	General soil value; 15 mg/kg applies to rice fields

the upper limit of statewide natural background, and any detection above this level is initially assumed to be from a release of arsenic-containing material (RIDEM, 1996). Kentucky's guideline (9.4 mg/kg; KEEC, 2004) represents the 95% upper confidence limit of the mean ambient background, and Illinois (IEPA, 2007) employs the mean concentration of soil samples from non-metro counties (11.3 mg/kg). Additionally, based on ambient background, New Jersey (NJAC, 2008) uses a concentration of 19 mg/kg and Montana uses 40 mg/kg, based on the 95% UCL of 209 native soil samples (MDEQ, 2005). These guidelines are all derived from different aspects of the land including varied backgrounds and soil types, but clearly are independent of considerations regarding potential health effects. Again, given the widespread existence of elevated arsenic concentrations in soil, many of which are naturally occurring, the question has been raised regarding an apparent absence of arsenic-related adverse health effects in those states.

3.3 Alternative Basis

At least one state agency, Indiana (IDEM, 2009), bases their soil arsenic screening guideline on a soil-plant-human exposure pathway uptake estimation. The Residential Closure Level for direct exposure in Indiana is 3.9 mg/kg, and is calculated based on the USEPA (2006) Soil Screening Guidance for vegetable uptake.

3.4 Bioavailability Considerations

The Florida Department of Environmental Protection (FDEP) commissioned the University of Florida to conduct a primate feeding study to determine the relative oral bioavailability of arsenic in several Florida-specific soils. Based on the results of that study (Roberts et al., 2001), the FDEP soil cleanup target levels for arsenic employ an oral bioavailability adjustment factor of 3x. On that basis, combined with other route-specific considerations, the Florida default direct exposure Soil Cleanup Target Level (SCTL) was adjusted from 0.8 mg/kg to 2.1 mg/kg for the cancer endpoint (FDEP, 2005). No other state agencies were identified which explicitly incorporate bioavailability of less than 100% in calculating state soil arsenic guidelines.

4. REGULATORY APPLICATION AND CHALLENGES

Due to arsenic's prevalence and long history of use, academic study, and regulation, it would seem that more wide-ranging consensus concerning health protective guidelines would exist in the regulatory community. The rather obvious, somewhat rhetorical, questions raised earlier regarding the lack of arsenic-related health effects, when ostensibly health-protective levels are exceeded on a routine basis, demonstrates the challenges that arsenic presents, particularly in soil and other non-drinking water exposures.

4.1 Case Studies

A relatively similar list of site types can be compiled across states, based on known industrial, commercial and recreational land uses. The following are selected examples of the categories of sites commonly identified where arsenic in soils can be a significant consideration.

Golf Courses - frequently have elevated soil levels due to historical arsenical herbicide/pesticide use. Site-specific risk-based protective levels are rarely exceeded when realistic exposures are considered (e.g., reduced frequency of exposure, exposure unit concentrations). Recent increases in reconfiguration and residential development of some golf courses has caused a recent focus on the issue.

Former Agricultural Properties - notable impacts from proper, legal, historical application of fertilizers. Can be financially and technically difficult to convert to residential use with sitewide exceedances of health-based criteria.

Railroad Rights of Way - common to find elevated soil arsenic due to historical arsenical herbicide use. Rails-to-trails conversions and other beneficial use projects typically must demonstrate that risks are limited based on planned use and engineering controls (e.g., paving, fencing, mulching, ground cover maintenance).

Coastal and Mountain Properties - may show elevated background soil arsenic as a result of marine environments or local geologic formations. Costly characterization often is needed to prove natural occurrence.

4.2 Historical Perception

In addition to the beneficial applications and natural occurrence which result in enhanced presence of soil arsenic relating to the land uses discussed above, arsenic has a historical media presence that often overshadows the apparent limited risk that it may pose from direct soil exposures. Arsenic is a classic, archetypal poison at high levels, yet it also is an historical and ongoing medicinal agent, currently approved for treatment of very specific cancer conditions (relapsed or refractory APL). Furthermore, recent media and regulatory attention pertaining to tanning beds being deemed "equally as deadly as arsenic and mustard gas" produced unfortunate comparisons. This leaves the impression that arsenic, no matter the exposure medium or conditions, is deadly. Even under the exposure condition that is closest to that which forms the basis for the toxicological guidance values, that of drinking water ingestion, the protective level is not health-based. Rather, the present arsenic MCL (10 ug/L) is based on considerations of technical and feasibility limitations of drinking water supply systems, and is promulgated at a level considerably higher than if it were strictly health-based. Further, the immediate former MCL was 50 ug/L for approximately 50 years. Yet, there evidently is no related cancer epidemic to report.

5. DISCUSSION

While an abundance of caution should always be the rule when assessing risk, the evaluation of potential risk from exposure to arsenic in soil suffers greatly from a lack of consensus from the regulating and scientific community. There recently has been proposed a downward change to toxicity guidance that, if implemented, will lower health-based soil guidelines 15-20x. In Florida alone, this will once again result in guidelines that are below 1 ppm, a level that is not significantly different than natural background throughout much of that state, and indeed the nation. In the classic toxicologist's quote from Paracelsus nearly 500 years ago, the dose makes the poison. In the case of arsenic in soil, it is evident that what that dose may be, and its health significance, is open to interpretation, and theoretically ranges from less than 0.05 parts per million to well over 100 parts per million. The continued reliance on the jumble of guidelines that are either health-based, but inappropriate for most soil exposures, or that are based on natural background, with no acknowledgement of potential toxicity at all, does not serve the science of risk assessment or toxicology well.

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