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Analysis of worldwide Regulatory Guidance Values for less frequently regulated elemental surface soil contaminants

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ABSTRACT

Guidance values are used to regulate exposure to surface soil contamination. In the United States, element guidance values have been promulgated by at least 6 federal agencies, 46 states, and several regional, city, county, territorial, and autonomous Native American jurisdictions. Guidance values have also been promulgated in at least 74 other United Nations member states. A companion manuscript examined the values applied to the eight most frequently regulated elements (Pb, Cd, As, Ni, Cr, Hg, Cu, and Zn) each for which there are at least 300 guidance values. This manuscript extends analysis to the second tier of contaminants (Sb, Ba, Be, Co, F, Mn, Mo, Se, Ag, Tl, Sn, and V) each for which there are at least 100 guidance values. These values span from 3.4 (for Sn) to 6.1 (for Be) orders of magnitude. Their distributions resemble those of lognormal random variables, but also contain non-random value clusters. On average, with the exception of cobalt, the values used in the U.S. are higher (less conservative) than those used elsewhere. Only about 44% of U.S. values and 31% of all values fall within uncertainty bounds computed for the U.S. Environmental Protection Agency health risk model applied to the elements considered.

1. Introduction

Surface soil contamination is a worldwide health concern. Concern is often highest for residential soils where children uptake contamination by ingestion, inhalation or dermal contact. Regulatory jurisdictions often attempt to control surface soil exposures with Regulatory Guidance Values (RGVs) that specify the maximum amount of a pollutant that may be present in the soil without prompting some form of action. However, jurisdictions seldom agree on the magnitude of contamination at which unacceptable health risks begin. Analysis of several classes of contaminants have demonstrated that RGVs often vary by five, six, or even seven orders of magnitude (see Jennings, 2009, 2010, 2011a, b, c, 2012a, b).

The work presented here is from a study that is examining the RGVs used worldwide to regulate exposures to the most important surface soil pollutants. Discussions of previous works on this general topic may be found in Jennings (2009), Kowalsky and Jennings (2012), and Jennings (2012a), and will not be repeated here. Although previous works have helped to develop insight about the values being applied in a limited number of jurisdictions, prior to this study, none have examined the full range of RGVs applied to the contaminants addressed here.

This manuscript is a companion to Jennings (2013), that presented analysis of the RGVs applied to the eight most frequently regulated elements (Pb, Cd, As, Ni, Cr, Hg, Cu, and Zn) for which there are at least 300 RGVs each. The work presented here extends this analysis to the second tier of 12 elements (Sb, Ba, Be, Co, F, Mn, Mo, Se, Ag, Tl, Sn, and V) for which there are at least 100 RGVs each.

2. Materials

This manuscript concentrates on the RGV's applied to antimony (Sb), barium (Ba), beryllium (Be), cobalt (Co), fluorine or fluoride (F), manganese (Mn), molybdenum (Mo), selenium (Se), silver (Ag), thallium (Tl), tin (Sn), and vanadium (V). For all of these elements, the RGVs apply to either their pure form or to the cumulative elemental composition of the compounds in which they are found. RGVs promulgated for specific compounds such as cobalt sulfate or selenium sulfide have not been included. RGVs specified for fluorine (F) and fluoride (F^-) have been combined into a single set of values. Generally, jurisdictions specify either F or F^-, but this distinction is more notational then physical. In units of milligrams per kilogram of soil (mg/kg) there is no practical distinction between the two.

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These elements are the "materials" of this work. Their RGVs are generally based on their health significance, so their health implications will be discussed briefly. More detailed summaries of the available toxicology information may be found in the National Library of Medicine, Hazardous Substances Data Bank (NLM/HSDB, 2012), the U.S. Environmental Protection Agency (USEPA) Integrated Risk Information System (USEPA/IRIS, 2012), the USEPA Technology Transfer Network (USEPA/TTN, 2012) and the U.S. Agency for Toxic Substances and Disease Registry (ATSDR, 2012). Information on how the available data have been interpreted by the International Agency for Research on Cancer (IARC, 2012a), Safe Work Australia (2012), the International Labour Organization (ILO, 2011), the *Deutsche Forschungsgemeinschaft* (DFG) (the German Research Foundation) (2012) and the World Health Organization International Program on Chemical Safety (WHO/IPCS, 2012) are also provided to help characterize how the health risks of these elements are being assessed elsewhere around the world. This information is summarized in Tables 1 and 2.

2.1. Antimony health risks

Antimony, Chemical Abstract Service number (CAS No.) 7440-36-0 National Institute of Standards and Technology (NIST, 2012) is a silvery-white metal that is often alloyed with lead to increase its hardness and mechanical strength. Antimony trioxide is used as a flame retardant in textiles and plastics, as a component of paints and enamels, and in fireworks. Antimony is listed at number 114 on the USEPA list of Priority Pollutants (USEPA, 2011), and at number 219 on the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) Priority List of Hazardous Substances (ATSDR, 2010). According to the USEPA Superfund Information System (USEPA/SIS, 2012), antimony has been identified at 348 national priority list (NPL) sites.

Human inhalation of antimony can yield eye and lung irritation, stomach pain, diarrhea, vomiting, and stomach ulcers. Accidental human ingestion has also produced stomach pain, colic, nausea, and vomiting.

Dermal exposure can lead to a rash (known as Antimony Spots) consisting of pustules similar to chicken pox. Women working in an antimony metallurgical plant also apparently had higher instances of spontaneous abortions, premature births, and gynecological problems. Animal studies indicate that high inhalation levels can lead to lung, heart, liver, and kidney damage. Lower inhalation exposures lead to eye irritation, hair loss, and lung and heart damage. Lung tumors and fertility problems have also been observed. Antimony has also been found to be mutagenic in bacteria (ATSDR, 1995a; NLM/HSDB, 2012; USEPA/IRIS, 2002a; USEPA/TTN, 2007a).

Currently, the USEPA antimony RGV is based solely on non-cancer ingestion risk (USEPA, 2012b). The degree to which antimony may be carcinogenic is not classified in the USEPA Integrated Risk Information System (USEPA/IRIS, 2002a, b, c), but antimony (as antimony oxide) is listed as a California Carcinogen by the California Environmental Protection Agency (CEPA, 2011) and as a category 2 carcinogen and category 3B germ cell mutagen by the DGF. However, antimony was not included in the list of known or reasonably anticipated to be carcinogens reported to Congress by the U.S. Department of Health and Human Services Public Health Services National Toxicology Program (USDHHS/NTP, 2011).

2.2. Barium health risks

Barium, CAS No. 7440-39-3 (NIST, 2012) is a silver or yellowish white soft metal most often found as barium sulfate for barium carbonate. Barium compounds are used in drilling mud. They are also used in the manufacture of paint, bricks, ceramics, glass, and rubber, and are sometimes used in medical applications to enhance x-ray imaging of the gastrointestinal tract. Barium does not appear on the USEPA list of Priority Pollutants (USEPA, 2011), but is listed at number 109 on the CERCLA Priority List of Hazardous Substances (ATSDR, 2010). The USEPA Superfund Information System (USEPA/SIS, 2012) indicates that barium has been identified at 400 NPL sites.

The health effects of barium depend on the solubility of the barium compound. Human ingestion of soluble forms can cause vomiting, abdominal cramps, diarrhea, difficulties in breathing, changes in blood pressure, facial numbness, and muscle weakness. In extreme cases, ingestion can lead to paralysis and possibly death. Animal studies have indicated that barium ingestion can lead to kidney damage, decreased newborn body weight, and death (ATSDR, 2007; NLM/HSDB, 2012; USEPA/IRIS, 2005a).

Currently, USEPA's barium RGV is based on non-cancer ingestion and inhalation risk (USEPA, 2012b). The degree to which barium is carcinogenic is rated as D – "not classifiable as to human carcinogenicity" in the USEPA Integrated Risk Information System (USEPA/IRIS, 2005a). Barium is not listed as a California Carcinogen (CEPA,

Table 1
Summary of cancer risk assessments for selected soil contaminants.

Soil contaminant	California carcinogen	U.S. Department of health and human Services 12th report of Congress	International Agency for Research on Cancer (IARC)	USEPA Integrated risk Information System (IRIS)	American Conference of Governmental Industrial Hygienists (ACGIH)
Antimony (Sb)	Listed (antimony oxide)	Not classified	Not classified	Not classified	Not classified
Barium (Ba)	Not listed	Not classified	Not classified	D – not classifiable	A4 (not classifiable as a human carcinogen)
Beryllium (Be)	Listed	Known Carcinogen	1 – carcinogen	B1 – probable human carcinogen	A1 (confirmed human carcinogen)
Cobalt (Co)	Listed (cobalt sulfate)	Reasonably anticipated to be carcinogenic (cobalt sulfate)	2B – possible human carcinogen	Not in IRIS	A3 (confirmed animal carcinogen with unknown relevance to humans
Fluorine (F)	Not listed	Not classified	3 – not classifiable	Not classified	Not classified
Manganese (Mn)	Not listed	Not classified	Not classified	D – not classifiable	Not classified
Molybdenum (Mo)	Not listed	Not classified	Not classified	Not classified	Not classified
Selenium (Se)	Listed (selenium sulfide)	Reasonably anticipated to be carcinogenic (selenium sulfide)	3 – not classifiable	D – Not classifiable	Not classified
Silver (Ag)	Not listed	Not classified	Not classified	D – Not classifiable	Not classified
Thallium (Tl)	Not listed	Not classified	Not classified	D – Not classifiable	Not classified
Tin (Sn)	Not listed	Not classified	Not classified	Not in IRIS	Not classified
Vanadium (V)	Listed (vanadium pentoxide)	Not classified	Not classified	Not in IRIS	Not classified