Appendix H. Root Uptake Factors

H.1 Introduction

Root uptake factors for crops have been estimated for toxic metals in the “Hot Spots” program. These toxic metals are subject to soil deposition and subsequent uptake by the roots of home raised produce. A root uptake factor is necessary to estimate a concentration in the plant from the concentration in the soil. An estimate of produce consumption can be applied to estimate dose to the residential receptor (Chapter 7). The soil-to-plant uptake factor (UF) is the ratio of the fresh weight contaminant concentration in the edible plant or plant part over the total concentration of the contaminant in wet weight soil:

$$UF = C_{f.w.plant} / C_{wet.w.\ soil} \qquad \textbf{(Eq. H-1)}$$

where: $C_{f.w.plant}$ = fresh weight concentration in the plant (mg/kg)

$C_{wet.w.\ soil}$ = wet weight concentration in soil (mg/kg)

In the last 25 years, a large number of studies have been published that investigated metal concentrations in edible plants grown in contaminated soils. Although most of these studies did not calculate the UF, data were often presented from which a UF could be calculated. OEHHA assembled the data from these studies into a database from which basic statistical analyses for chemical UFs were determined. The volume of studies that could be included in the database is quite large for some inorganic metals, with new studies frequently published. Our database is not an exhaustive compilation of all plant uptake studies published, however, enough data were found to reasonably estimate default UFs for most of the toxic metals and metalloids of concern.

The UFs calculated by OEHHA are based on the total metal concentration in soil and reflect the fact that most crop uptake studies estimate total metal soil concentration, usually by extraction with strong or moderately strong acids (e.g., 4 N sulfuric acid). A smaller body of uptake studies uses various mild soil extraction processes (e.g., extraction with diethyltriaminopentaacetic acid) to estimate plant bioaccessible metal concentrations in soil. Once more studies become available using an established method for estimating bioaccessible metals in contaminated soil, OEHHA may also consider developing an algorithm that incorporates a bioaccessible metal uptake factor.

The ability for crops to accumulate and translocate toxic inorganic metals and metalloids to edible parts depends to a large extent on soil and climatic factors, plant genotype and agronomic management (McLaughlin et al., 1999). In order to be most applicable to Hot Spots risk analysis, a set of criteria was applied for the selection of data used in developing soil-to-plant uptake factors.

Data used to determine root uptake factors were limited to studies that estimated contaminant concentrations in edible portions of crops raised and harvested at maturity for human consumption. Crops that are commonly grown in backyard gardens in California were considered most relevant. For example, plant uptake studies in crops grown in tropical climates were not included in the database. Grain crops such as wheat and rice were also not included in the database because these crops are unlikely to be grown in backyard gardens. In most field studies background soil contaminant levels were unknown or not presented. However, field studies were included in the database if the study indicated that the soil was contaminated due to human causes, or that the soil contaminant concentration was considered above background levels.

Another data selection factor was soil pH because soil pH is a major influence on root uptake. Most agricultural soils in California are near neutral, with a geometric mean pH=7.2 (Holmgren et al., 1993). The range of pHs for most agricultural soils in California are roughly estimated at between 5.5 and 7.6. Thus, plant uptake studies that investigated soils with pH values within this range were considered most useful for estimating soil-to-crop uptake factors. Acidic soils tend to increase the bioavailability of divalent cationic metals such as cadmium, lead, and mercury. UFs based on acidic soils may overestimate metal uptake from pH neutral soils.

A distinction is made in the database for contaminant source between freshly added inorganic salts and other forms of the chemicals. In general, fresh addition of metal salts to soil in laboratory experiments will represent the most available form of the metal to plants. UFs developed from these studies likely represent an upper limit for plant accumulation. Where possible, UFs were calculated based on field studies that estimated plant uptake due to human-caused contamination of soils. These sources primarily included mine waste, smelter deposits, vehicle and other urban emissions, other industrial sources, wastewater effluent, compost, fertilizer, dredged material, sewage sludge, fly ash and flue dust. Ideally, UFs would be based on airborne deposition of contaminants due to emissions from nearby industrial facilities. However, uptake data from these sources were often very limited.

Most of the plant uptake studies summarized in the database presented their contaminant concentration results on a dry weight basis for both the plants and the soil. However, the soil-to-plant UF in Eq. 7.6 (Chapter 7) is expressed as a ratio of fresh weight crop concentration per wet weight soil concentration. To adjust the soil-to-plant UFs to a fresh weight crop basis, dry-to-wet weight fractions of edible portions of crops were applied using literature sources containing water content data of raw fruits and vegetables (Watt and Merrill, 1975; Baes et al., 1984; USDA, 2009). A default value of 0.8 was applied to all UFs for the dry-to-wet weight adjustment of soil, unless water content data of soil was presented in the study (Clement Associates, 1988).

As a result, two types of soil-to-plant UFs can be generated for each metal contaminant: one based on the dry weight plant over dry weight soil, and the other based on fresh weight plant over wet weight soil. A UF based on dry weights of plant and soil may be beneficial because the ratio avoids the naturally wide variations in water content of the crops and the soil. On the other hand, estimates of fruit and vegetable consumption are based on fresh weight values for the crops, which were grown in irrigated soils. This type of UF is most applicable for contaminant exposure via the crop consumption pathway (Eq. 7.6).

Finally, some studies also presented uptake data for reference soils. This information was also entered into the database to estimate crop uptake based on control soils as well as crop uptake specifically due to deposited contaminants (i.e., contaminated soil minus control soil metal concentration). Metals of concern naturally present in soils may be largely present in the mineral fraction of the soil and not available for uptake by plants. However, it may be beneficial to know what the background soil-to-plant UF is for toxic metals to estimate the impact of anthropogenic sources of the same metals is on the soils and plants.

The database of the studies used in the analysis is presented at the end of this appendix. Studies were grouped according to each metal/metalloid for comparison purposes.

H.2 Arsenic

Arsenic can be present in well-drained soil as $H_2AsO_4^{-1}$ if the soil is acidic or as $HAsO_4^{-2}$ if the soil is alkaline (Bhumbla and Keefer, 1994). Arsenite (As(III)), the reduced state of inorganic arsenic, is a toxic pollutant in natural environments. It is much more toxic and more soluble and mobile in soil than the oxidized state of inorganic arsenic, arsenate (As(V)). Under flooded conditions, As(III) would dominate, whereas aerobic conditions would favor the oxidation of As(III) to As(V). Arsenic accumulates in roots of plants grown on soils contaminated by arsenic pesticides. However, arsenic is not readily translocated to above-ground parts.

Although background mean levels of arsenic in U.S. agricultural soils could not be located, a review by Wiersma et al. (1986) showed mean levels of arsenic in European and Canadian agricultural soils to be in the range of 5 to 12 mg/kg dry soil. Kloke et al. (1984) reports that the range of arsenic in arable land to be 0.1 to 20 mg/kg dry soil. The typical dry weight concentration of arsenic in plants has been listed as 0.1 to 5 mg/kg (Vecera et al., 1999). In this document, all crops grown in As-polluted soils had an overall average dry weight arsenic concentration of about 2.5 mg/kg, which is within the range of typical plant concentrations.

Table H.1 Distribution Parameters for Arsenic Fresh Weight Soil-to-plant Uptake Factors

	Leafy	Exposed	Protected	Root
n	27	22	8	17
minimum	0.000275	0.0000538	0.000115	0.000338
maximum	0.055	0.132	0.27	0.045
mean	0.00983	0.0158	0.066	0.00828
median	0.00531	0.00138	0.032	0.00399
90th percentile	0.0257	0.0403	0.19	0.0236
95th percentile	0.0481	0.0674	0.23	0.0361

It was observed that lower UFs were recorded in plants growing in high As-polluted soils compared to plants growing in low-level As-polluted soils. This finding, in part, led to the large range in UF values shown in Table H.1 for some types of crops. For example, in soils with low-level As contamination of < 12 mg/kg, a UF of 0.01 was calculated for both exposed and leafy crops. In exposed and leafy crops grown in soils with >12 to 745 mg/kg As (mean: 343 mg/kg), calculated UFs were 0.0002 and 0.002, respectively. This seems to suggest that many crops have the ability to resist uptake, or have a high excretion rate, of excessive amounts of As in highly polluted soils. The crop UFs in Table H.1 are based on the arithmetic mean value for low- to high-level As polluted soils.

H.3 Beryllium

Very little data could be found regarding plant uptake of beryllium from the soil. Measurable amounts of beryllium in plants are rarely observed and the toxicity of this metal to plants is reported to be high (Shacklette et al., 1978; Baes et al., 1984). Kloke et al. (1984) estimates that a general dry weight plant/soil transfer coefficient for Be is in the range of 0.01 - 0.1, similar to that found for lead and mercury.

Single soil-to-plant data points from Baes et al. (1984) for leafy and protected crops were used in Table 7-6 to represent these particular crop types. These were the only UFs that could be located in the literature. Due to expected similarities in soil-to-plant transfer, the lead UFs for root and exposed crops were used to represent the root and exposed UFs for beryllium.

H.4 Cadmium

Cadmium has the most extensive literature on root uptake of any of the toxic metals Compared to Pb, Cd is readily taken up by plants, but unlike the other heavy metals, Cd is not phytotoxic at low plant concentrations that pose a concern to human health (McLaughlin et al., 1999). Cadmium exists in solution mostly as the divalent cation, Cd^{2+}. Plant uptake of Cd is governed by a number of factors that include soil pH, organic matter, cation exchange capacity, clay type and amount, hydrous metal oxides, carbonates, and other inorganic compounds (Mahler et al., 1987; McLaughlin et al., 1996). Acidic soils, and soils with lower clay and humus content will increase availability of Cd to plants.

The mean concentration of Cd in uncontaminated U.S. agricultural soils is 0.27 mg/kg d.w., with 5th and 95th percentiles of 0.036 and 0.78 mg/kg d.w., respectively (Holmgren et al., 1993). The mean concentration of Cd for field-contaminated soils reviewed in this document was about 8 to 9 mg/kg d.w., with a range of 0.16 to 106.5 mg/kg d.w. Typical dry weight levels of Cd in plants are expected to be between 0.1 and 1 mg/kg (Vecera et al., 1999). In this document, the overall Cd concentration in crops grown in Cd-polluted soil was about 6 mg/kg.

Figure H.1. Cumulative distribution of the leafy crop UFs for cadmium from field studies in the literature (n=73, skewness=3.05, kurtosis=9.09)

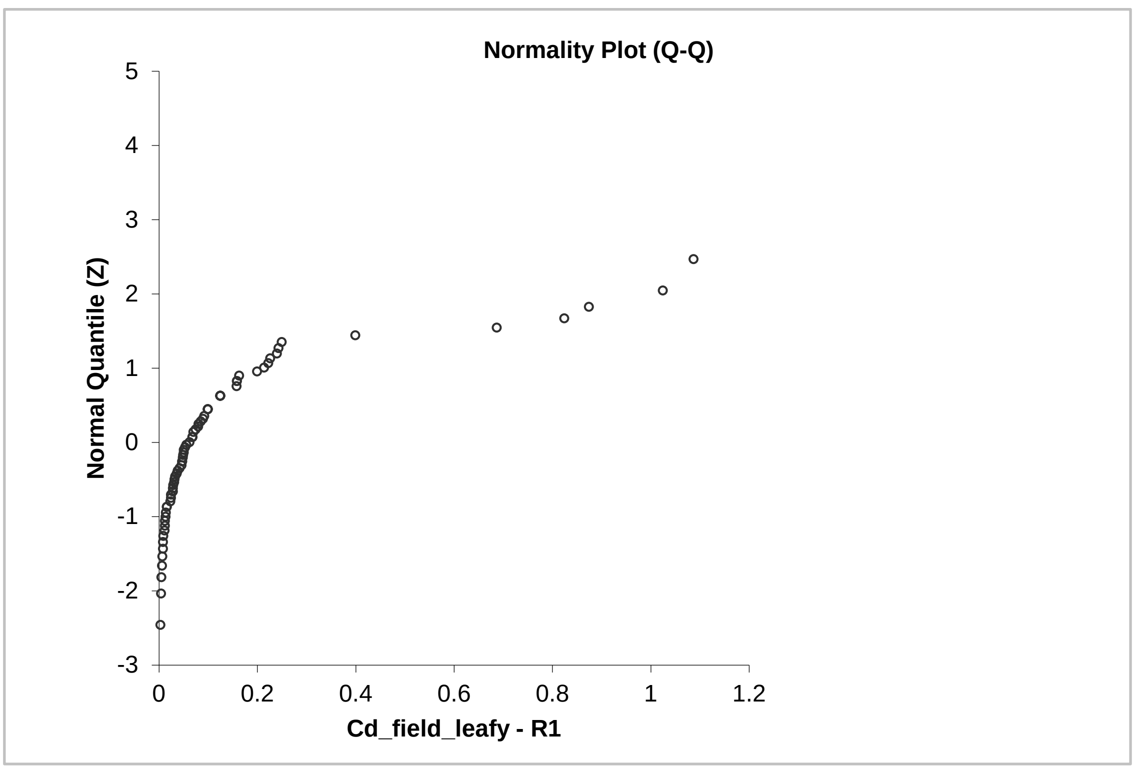

Table H.2 presents the UF distributions from field data only. UFs calculated from laboratory studies in which Cd salts were added to soils were not included in Table H.2, although there are a considerable number of these types of studies. Comparison of UFs calculated from field and Cd salt studies showed significantly greater UFs were obtained in crops grown in Cd salt-contaminated soil. For example, the mean leafy UF from Cd salt studies was 0.5 (n=27), which was significantly greater ($p<0.0001$) than the leafy UF of 0.1 based on field studies (Table H.2). The field studies were chosen to calculate the UFs because they are likely more relevant for “Hot Spots” facility soil contamination.

Table H.2: Percentile Distribution for Cadmium Fresh Weight Soil-to-plant Uptake Factors

	Leafy	**Exposed**	**Protected**	**Root**
n	81	41	27	62
minimum	0.00375	0.0001	0.0002	0.00113
maximum	1.09	0.148	0.0688	0.913
mean	0.139	0.0216	0.0134	0.0683
median	0.0688	0.008	0.0064	0.0244
90^{th} percentile	0.244	0.0541	0.0294	0.124
95^{th} percentile	0.688	0.0863	0.0552	0.172

H.5 Chromium VI

Exposure to hexavalent chromium (Cr(VI)) as a contaminant in soil has been a contentious and complex risk assessment issue that has never been satisfactorily resolved. In both industrial and environmental situations Cr(III) and Cr(VI) can inter-convert, with reduction of Cr(VI) to Cr(III) generally being favored in most soils and sediments. Rapid oxidation of a portion of Cr(III) salts or hydroxides added to almost any soil with a pH above 5 was found to occur readily, provided the soil sample was fresh and kept moist and directly from the field (Bartlett and James, 1988). However, oxidation of Cr(III) to Cr(VI) in field soils is slow compared to well mixed soils in laboratory studies, and given opportunities for its reduction, accumulated Cr(VI) from inorganic sources may rarely be measurable.

Cr(VI) added to soils may be reduced, or absorbed, or may remain in solution depending on the organic matter content, pH, and texture of the soil (Cary, 1982). In neutral to basic soil, chromium will be more available to growing plants than in acidic soil probably due to the increased stability and presence of Cr(VI) in the basic pH range.

For example, when Cr(VI) was added to near-neutral pH soil (6.65) under field conditions, most of the Cr(VI) was extracted from the soil unchanged three weeks later (Bloomfield and Pruden, 1980). Under the same field conditions, most of the added Cr(VI) to an acidic soil (pH 4.20) was reduced three weeks later. These results suggest that in some neutral pH agricultural soils, such as those found in California, constant deposition of Cr(VI) may result in accumulation of Cr(VI) in the soil and ground water.

As a soluble anion, Cr(VI) readily penetrates cell membranes, whereas Cr(III) is soluble at biological pHs only when organically complexed in low molecular weight organic complexes and, therefore, soil forms probably do not penetrate membranes (Bartlett and James, 1988). The difficulty for risk assessors is attempting to estimate what proportion of chromium deposited as Cr(VI) to soil will be available for plant uptake, presumably as Cr(VI). This problem is compounded by the difficulty of estimating the actual speciation of chromium in biological tissues during analysis. As a result, most studies only measure total chromium contents of plant parts.

Cr(III) in soil probably does not penetrate plant cell membranes as such, but is thought to undergo enhanced solubility in soil due to organic acids exuded by roots (James and Bartlett, 1984; Bartlett and James, 1988). This in turn leads to an increased oxidation of Cr(III) to Cr(VI) by soil manganese oxides. The oxidation of Cr(III) to anionic Cr(VI) enables its absorption by the roots. However, once absorbed by root tissues, it appears that most of the Cr(VI) is reduced again to Cr(III) and retained by the roots in a tightly bound or insoluble form or in a soluble complex (e.g., trioxalato chromate(III)) that is not translocated to the above-ground plant parts.

Evidence for the low translocation of chromium from roots has been observed by Lahouti (1979), in which crops that accumulated chromium from nutrient solutions labeled with either ^{51}Cr(III) or ^{51}Cr(VI) retained about 98% of the elements in the roots. Of nine species of crops examined, the roots supplied with ^{51}Cr(III) contained more chromium than those supplied with ^{51}Cr(VI), but chromium added as ^{51}Cr(VI) was slightly better translocated to the shoots. In another study, onion plants were grown in soil after equivalent doses (total dose not provided) of either Cr(III) or Cr(VI) added to the soil (Srivastava et al., 1994). At the lower levels that did not injure the onion plants, the chromium concentration in the plants with Cr(VI) added to soil was only marginally higher than those with Cr(III) added to soil, with most of the chromium retained in the roots and bulb.

This finding seems to suggest that much of the chromium, either added as Cr(VI) or Cr(III), had reached an equilibrium in the soil prior to uptake by the roots.Field studies in which soils were contaminated by anthropogenic sources of Cr(VI) were difficult to come by. Soils contaminated with chromium, generally from sewage sludge, tannery waste, inorganic native chromium in mine waste, are mainly present as Cr(III). Often, the contaminated soils did not exhibit concentrations above the range of typical soil chromium levels of 2 to 50 mg/kg (Kloke et al., 1984), and no chromium control level was provided in the study. Quantitative data for plant uptake of chromium added as Cr(VI) in greenhouse studies are also limited. Cary et al. (1977a, 1977b) added Cr(VI) as K_2CrO_4 to soil over the first 29-40 days after seeding several crop varieties in pots, and then harvested the crops at maturity 70-110 days after seeding. From these data, leafy, exposed and protected crop UFs for total chromium were estimated (Table H.3). For the root UF, it was observed that roughly 10% of the chromium added as Cr(VI) to soil was incorporated in the above-ground plant parts, with the remainder incorporated into roots and bulbs (Srivastava et al., 1994). The difference between above-ground and root chromium was also reflected by a 10-fold greater concentration of chromium in roots compared to above-ground plant parts. Thus, the root UF is 10-fold greater than the leafy UF. It is currently unknown what proportion of chromium as Cr(VI) will be found in edible crops following absorption and translocation from the roots (Cary, 1982; Kimbrough et al., 1999). Bartlett and James (1988) surmised that if Cr(III) were to be translocated to above-ground plant parts, it is not unreasonable to think that if it enters the chloroplasts it might be oxidized to Cr(VI) in the powerful oxidative environment within the chloroplasts where water is oxidized to O^{2-}. Skeffington (1976) showed that 0.5% of the Cr(III) mixed with ground fresh barley roots was oxidized to Cr(VI). These data would suggest that a fraction of the chromium in roots is present as Cr(VI). Until further characterization of the form of chromium found in edible crops is determined, the health protective assumption is that the chromium found in crops due to root uptake is in the form of Cr(VI).

Table H.3: Crop uptake factors for total chromium, added originally as chromium(VI) to the soil[a]

	Leafy	Exposed	Protected	Root
N	3	1	3	-[b]
Minimum	0.18	-	0.0034	-
Maximum	0.42	-	0.19	-
Mean	0.3	0.02	0.07	3

[a] Data were too limited to determine percentiles.
[b] No quantitative data could be found for a root UF. The general finding that root levels of chromium are 10-fold greater than above-ground plant parts was to devise a root UF.

H.6 Fluoride

Fluoride (F) is strongly sorbed to soil when added as a salt, much stronger than the other halide salts of iodine, bromine and chlorine (Sheppard et al., 1993). The generally low soluble F in most soils coupled with the fact that the root endodermis acts as a barrier means that transport from root to shoot will be limited (Davison, 1982). The lack of soil-to-plant field data for fluoride resulted in a reliance on laboratory studies which added fluoride salts to the soils. The resulting UFs are shown in Table H.4.

The most important F exposure route for plants is uptake via airborne deposition of soluble fluorides of HF and particulate fluoride salts on leaf surfaces. Fluoride that deposits on leaf surfaces can be taken up through stomata of leaves once it deposits on the surface. Uptake of F into plant leaves occurs by passive permeation of the undissociated HF molecule across the plasmalemma (Kronberger, 1987). Thus, HF behaves like a weak acid (pKa = 3.4) when dissolved in water, where the ionic species becomes trapped within membrane-surrounded compartments after nonionic diffusion. Little fluoride moves downward in plants to roots, from leaf to leaf or from leaves to fruits. Assessing fluoride UFs for leafy crops near airborne industrial emissions of fluoride compounds may eventually require a different algorithm to estimate airborne fluoride accumulation in leafy crops.

Tea plants (*Camellia sinensis*) are known to accumulate high concentrations of F in their leaves from soil containing elevated levels of F, resulting in considerable amounts of F in tea beverages (Davison, 1983). However, it is not known if significant cultivation of tea plants occurs in California. There is also some evidence spinach can accumulate F from soil to a greater degree than other leafy crops (Kumpulainen and Koivistoinen, 1977). The maximum fluoride UF for leafy crops shown in Table H.4 is for spinach.

Table H.4: Fresh weight soil-to-plant uptake factors for fluoride[a]

	Leafy	Exposed	Protected	Root
N	5	-[b]	1	2
Minimum	0.0006	-	-	0.003
Maximum	0.16	-	-	0.014
Mean	0.036	0.004	0.004	0.009

[a] Data were too limited to determine percentiles.
[b] No quantitative data could be found for an exposed crop UF, so the protected crop UF was used

H.7 Lead

Deposited lead (Pb) is strongly retained by most soils, resulting in lower plant concentrations (and lower UFs) relative to more bioaccessible metals such as cadmium and nickel (McLaughlin et al., 1999). Because of the usually low soil-to-root uptake, the above-ground plant parts are likely predominantly contaminated by airborne deposition of lead-containing dust or aerosols onto the plant surface (McBride, 1998). This finding emphasizes the importance of selecting studies in which the leafy plant samples are thoroughly washed prior to assessing root uptake and translocation of lead. Because inorganic lead most often exists as a divalent cation, maintaining alkaline soil conditions will reduce lead mobility in soil, while acidic soil conditions has been shown in some cases to increase soil mobility and uptake of lead through plant roots.

The mean concentration of Pb in uncontaminated U.S. agricultural soils is 12.3 mg/kg, with 5^{th} and 95^{th} percentiles of 4.0 and 23.0 mg/kg, respectively (Holmgren et al., 1993). The range of Pb concentrations in field-contaminated soils reviewed in this document was large, ranging from 11 mg/kg dry soil to nearly 5500 mg/kg dry soil. Typical dry weight concentrations of Pb in plants are reported to be 0.1 to 5 mg/kg (Vecera et al., 1999), whereas the overall average Pb concentration in crops grown in Pb-polluted soil reviewed in this document was about 9.5 mg/kg.

Table H.5: Percentile distribution for lead fresh weight soil-to-plant uptake factors

	Leafy	Exposed	Protected	Root
n	77	38	24	57
minimum	0.0000375	0.00002	0.000075	0.0000425
maximum	0.0413	0.0475	0.0278	0.0375
mean	0.00770	0.00693	0.00282	0.00403
median	0.00298	0.00228	0.000912	0.00125
90^{th} percentile	0.0248	0.0214	0.00465	0.00962
95^{th} percentile	0.0308	0.0406	0.00711	0.015

H.8 Mercury

Determining the crop uptake of inorganic mercury (Hg) from soil can be problematic. (Caille et al., 2005) found that following application of radiolabeled $^{203}HgCl_2$ to sediment in a pot experiment, 33-73% of the leaf content in cabbage, rapeseed and pasture grass was due to volatilized Hg absorbed into the leaves. Presumably, the applied inorganic Hg^{2+} was emitted from the soil after reduction to Hg^0 in the soil whereupon it was absorbed by the leaves. Lindberg et al. (1979) observed the same phenomena in alfalfa grown in a chamber, in that above-ground plant parts primarily absorbed Hg vapor released from the soil originally contaminated with mercury mine waste including cinnabar (mercury(II) sulfide). However, the root levels of mercury were determined by direct uptake from contaminated soil and reflected the total Hg concentrations in the soil. Significantly, any Hg vapor emitted by a facility could also be absorbed directly onto leafy crops.

Nearly all studies examined by OEHHA for crop Hg uptake from soil measured total Hg content and did not account for potential volatilization of elemental Hg from soil. Therefore, the soil-to-plant UF for mercury in above-ground plant parts (primarily leafy) includes both root uptake from soil and leaf uptake through volatilization from soil. It is unclear what portion of Hg oxidizes to inorganic Hg once absorbed by leaves, although mercury in food stuffs are mainly in the inorganic form (WHO, 1991). Therefore, a health protective assumption is that the Hg in crops is all in the inorganic form.

Another possible factor to consider is the uptake of methyl mercury (MeHg) by plants. Although it is not expected that Hot Spots facilities would emit MeHg, a fraction of total Hg emitted and deposited to soil could be converted to MeHg in soil. Generally, this may not be a concern in cropland soils, as the content of MeHg would be very low. Nevertheless, results by Gnamus et al. (2001) observed MeHg to be approximately 10 times more phytoavailable then total Hg in an ecotoxicology field study of an Hg-polluted region. Phytoavailability of both total Hg and MeHg increases with decreasing soil pH below 7 and decreased soil content of organic matter.

In rice paddies exposed to Hg smelting and mining facilities, it was found that the percent of total Hg in soil that was MeHg ranged from 0.092 to 0.003 percent (Horvat et al., 2003). However, the percent of total Hg that was MeHg in brown rice grown in the contaminated region ranged from 5 to 84 percent, indicating preferential uptake of MeHg from soil. The resulting UFs for rice ranged from 550 to 6000, suggesting rice may be a high accumulator of MeHg. However, the risk assessment conducted by Horvat et al. (2003) could not establish a clear correlation between total Hg and MeHg in soil and in rice, indicating that uptake and retention of Hg in rice is influenced by a number of factors other than total Hg in soil. Although background mean levels of Hg in U.S. agricultural soils could not be located, a review by Wiersma et al. (1986) showed mean levels of Hg in European and Canadian agricultural soils to be in the range of 0.06 to 0.2 mg/kg dry soil. On average, the concentration of Hg in polluted soils reported in studies reviewed for this document was about 3.6 mg/kg. Typical dry weight plant concentrations of Hg are listed as 0.001 to 0.3 mg/kg (Vecera et al., 1999). In this document, the overall Hg concentration in crops grown in Hg-polluted soils was about 0.2 mg/kg.

Table H.6: Percentile distribution for mercury fresh weight soil-to-plant uptake factors

	Leafy	Exposed	Protected	Root
n	33	23	15	18
minimum	0.00021	0.000248	0.000106	0.00111
maximum	0.0813	0.0938	0.0363	0.0588
mean	0.0163	0.00855	0.00804	0.0119
median	0.00875	0.00225	0.00514	0.00553
90th percentile	0.0478	0.0175	0.016	0.0274
95th percentile	0.06	0.0198	0.0223	0.0545

H.9 Nickel

Nickel (Ni) is considered to be one of the more mobile heavy metals in soils (Sauerbeck and Hein, 1991). However, in contrast to Cd, the toxicity of Ni in mammals is lower and phytotoxicity occurs at lower concentrations. Similar to other divalent, cationic metals, acidification of soil increases bioavailability, and liming of soil decreases bioavailability, of Ni to plants. The UF data presented in Table H.7 are based on field-contaminated studies. One study that added Ni salts to soil can be found in the database, but appeared to result in increased plant uptake compared to the field data and was, thus, not included for the UF calculations.

The mean concentration of Ni in uncontaminated U.S. agricultural soils is 23.9 mg/kg, with 5th and 95th percentiles of 4.1 and 56.8 mg/kg, respectively (Holmgren et al., 1993). The mean concentration of Ni for field-contaminated soils reviewed in this document was about 70 mg/kg d.w., with a range of 13 to 122 mg/kg d.w. Typical Ni levels in plants are expected to be in the range of 0.1 to 5 mg/kg dry weight (Vecera et al., 1999). In this report, the overall mean dry weight concentration of Ni in crops was about 9 mg/kg.

Table H.7 Percentile distribution for nickel fresh weight soil-to-plant uptake factors

	Leafy	**Exposed**	**Protected**	**Root**
n	11	13	9	11
minimum	0.00135	0.00025	0.00875	0.00163
maximum	0.0375	0.00625	0.075	0.0175
mean	0.0145	0.00293	0.0305	0.00638
median	0.00888	0.00224	0.025	0.00463
90th percentile	0.0250	0.00610	0.055	0.0125
95th percentile	0.0313	0.00618	0.065	0.0150

H.10 Selenium

The major inorganic species of selenium (Se) in plant sources is selenate, which is translocated directly from the soil and is less readily bound to soil components than selenite (McLaughlin et al., 1999; Rayman, 2008) .The more reduced forms, selenide and elemental Se, are virtually insoluble and do not contribute directly to plant uptake. Other major Se species in plants are biosynthesized, including selenomethionine, smaller amounts of selenocysteine, and Se-containing proteins. At pH values around 7.0 or greater, oxidation to the more soluble selenate ion is favored. Thus, endemic vegetation in alkaline, seleniferous soil of the western U.S. has evolved that is highly tolerant and can hyperaccumulate Se (McLaughlin et al., 1999).

However, potential Se-accumulators that are food sources for humans are largely limited to Brazil nuts, a tree crop that is not grown in California (Rayman et al., 2008). Crops of the Brassica (e.g., broccoli, cabbage) and Allium (e.g., onions, garlic, leeks, chives) families appear to more readily accumulate Se than other crops, and form the Se detoxification products Se-methyl-selenocysteine and gamma-glutamyl-Se-methyl-selenocysteine. Se-enriched plants have been shown in animals to have potent anti-tumor effects that are attributed to these Se detoxification products (Rayman et al., 2008).

Though there is no direct evidence in humans, it is generally accepted on the basis of animal studies that inorganic forms of Se are more acutely toxic than organic species, selenite being slightly more toxic than selenate (Rayman et al., 2008). In chronic studies of humans, lower toxicity is seen with organically bound Se, although there are limited data on the toxicity of individual compounds.

Selenomethionine is known to be the main Se species present in the diet of Chinese who developed chronic selenosis from consumption of high-Se-containing maize and rice. Based on these Chinese studies, 1540 and 819 µg/day were established as the LOAEL and NOAEL, respectively, for total daily Se intake (Rayman, 2008). However, the levels found in crops rarely accumulate greater than 25-30 µg/g even in seleniferous areas suggesting other sources of Se are also contributors to chronic Se toxicity.

Although the UF data for Se were limited, an overall mean dry weight crop Se concentration of about 4 mg/kg was calculated from the reviewed studies, with a maximum crop concentration of 19 mg/kg. Kloke et al. (1984) observed a general dry weight UF for Se in plants would be 0.1 to 10. Based on the studies examined in this document, an overall dry weight uptake factor of 0.9 was calculated for crops grown in Se-polluted soils, which was within the range predicted. Field contamination studies were the primary source of the UF distribution data in Table H.8. The Se pollution sources included mainly fly ash, smelters and compost.

Table H.8: Percentile distribution for selenium fresh weight soil-to-plant uptake factors

	Leafy	Exposed	Protected	Root
n	12	10	7	10
minimum	0.006	0.00132	0.00625	0.005
maximum	0.25	0.25	1.25	0.375
mean	0.0587	0.0415	0.256	0.0689
median	0.0328	0.0106	0.07	0.0195
90th percentile	0.12	0.104	0.678	0.15
95th percentile	0.179	0.177	0.964	0.263

H.11 Summary and Recommendations

OEHHA recommends the root uptake factors in Table H.16 for metals and metalloids.

Table H.16 Recommended Soil-to-plant uptake factors for inorganic metals and metalloids in edible crops[a]

Element	Leafy	Exposed	Protected	Root
Arsenic	1×10^{-2}	2×10^{-2}	7×10^{-2}	8×10^{-3}
Beryllium	2×10^{-4}	8×10^{-3}	3×10^{-4}	5×10^{-3}
Cadmium	1×10^{-1}	2×10^{-2}	1×10^{-2}	8×10^{-2}
Chromium (VI)	3×10^{-1}	2×10^{-2}	7×10^{-2}	3×10^{0}
Fluoride	4×10^{-2}	4×10^{-3}	4×10^{-3}	9×10^{-3}
Lead	8×10^{-3}	7×10^{-3}	3×10^{-3}	4×10^{-3}
Mercury	2×10^{-2}	9×10^{-3}	1×10^{-2}	2×10^{-2}
Nickel	1×10^{-2}	3×10^{-3}	3×10^{-2}	6×10^{-3}
Selenium	6×10^{-2}	4×10^{-2}	3×10^{-1}	7×10^{-2}

[a] Soil-to-plant UFs represent the fresh weight concentration of a contaminant in the plant part over the wet weight concentration of contaminant in the soil.

H.12 Database

The database that lists all of the studies, values, with references is presented as Table H.9-1 through Table H.15-4 in the following pages.

Abbreviations in these tables:

soil conc bckd: the concentration of the chemical in the control soil samples

soil conc contam: the concentration of the chemical in the soil treated with the chemical

tissue conc bckg: the concentration of the chemical in the control tissue samples of the crop

tissue conc contam: the concentration of the chemical in the tissue of the crop grown in the soil treated with the chemical

contam: the related sample treated with the chemical

wt: weight

dw: dry weight

wet w: wet weight

ww: wet weight

Calculation:

$$\text{Uptake factor (contam) dry wt} = \frac{\text{tissue conc contam dry wt} - \text{tissue conc bckg dry wt}}{\text{soil conc contam} - \text{soil conc bckd}}$$

Uptake factor (contam) wet wt plant/dw soil = Uptake factor (contam) dry wt × dry-to-wet wt conversion factor

$$\text{Uptake factor (contam) ww plant/wet w soil} = \frac{\text{Uptake factor (contam) wet wt plant/dw soil}}{\text{dry-to-wet weight fraction for soil (0.8)}}$$

Table H.9-1 Arsenic field studies on leafy crops.

Study Type	soil conc bckd mg/kg	soil conc contam mg/kg	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
Field		377	leaf mustard		20	0.05305	0.08	0.004244	0.005305	Clemente et al. (2005)
25% mine waste - greenhouse	23.3	187	lettuce	5.47	21.5	0.11497	0.045	0.005	0.00625	Cobb et al., (2000)
field-fly ash - pot	8.8	9.5	cabbage	0.2	0.3	0.03	0.08	0.003	0.00375	Furr et al. (1978a)
Field		6.04	Chinese cabbage			0.025	0.08	0.002	0.0025	Huang et al. (2006)
Field		6.04	leaf mustard			0.07125	0.08	0.0057	0.007125	Huang et al. 2006
Field		6.04	lettuce			0.046	0.05	0.0023	0.002875	Huang et al. 2006
Field		6.04	pakchoi			0.04625	0.08	0.0037	0.004625	Huang et al. 2006
Field		6.04	water spinach			0.07375	0.08	0.0059	0.007375	Huang et al. 2006
Field			amaranthus			0.55	0.08	0.044	0.055	Huq and Naidu (2005)
Field			cabbage			0.44	0.08	0.0352	0.044	Huq and Naidu 2005
wood preserve. Factory-field	3.4	17.9	kale	0.078	0.1	0.0056	0.08	0.00045	0.000563	Larsen et al., (1992)
wood preserve. Factory-field	3.4	17.9	lettuce	0.048	0.086	0.0048	0.05	0.00024	0.0003	Larsen et al., 1992
mining, smelting-field		446.64	cabbage		1.48	0.0033	0.08	0.00027	0.000338	Li et al., (2006)
mining, smelting-field		446.64	cabbage		1.21	0.0027	0.08	0.00022	0.000275	Li et al., 2006
mining, smelting-field		446.64	Chinese cabbage		1.85	0.0041	0.08	0.00034	0.000425	Li et al., 2006
mining, smelting-field		446.64	spinach		1.37	0.0031	0.08	0.00025	0.000313	Li et al., 2006
Field		6.01	amaranth		0.67	0.11148	0.08	0.008918	0.011148	Liu et al. (2006)
Field		6.01	cabbage		0.81	0.13478	0.08	0.010782	0.013478	Liu et al. 2006
Field		6.01	celery		0.49	0.08153	0.08	0.006522	0.008153	Liu et al. 2006
Field		6.01	Chinese cabbage		0.45	0.07488	0.08	0.00599	0.007488	Liu et al. 2006
Field		6.01	Chinese chive		0.57	0.09484	0.08	0.007587	0.009484	Liu et al. 2006
Field		5.54	leek		0.62	0.11191	0.08	0.008953	0.011191	Liu et al. 2006
field		6.01	pakchoi		3	0.49917	0.08	0.039933	0.049917	Liu et al. 2006

Table H.9-1 Arsenic field studies on leafy crops.

Study Type	soil conc bckd mg/kg	soil conc contam mg/kg	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
pot	9.83	745	Radish	0.28	14.4	0.01933	0.08	0.001546	0.001933	Mathe-Gaspar and Anton (2002)
pot	9.83	745	Radish	0	48.7	0.06537	0.08	0.00523	0.006537	Mathe-Gaspar and Anton 2002
Env polluted soil - field		118	lettuce		7.2	0.06102	0.049	0.003	0.00375	Mattina et al., (2003)
Env polluted soil - field		125.9	spinach		1.55	0.012	0.093	0.0011	0.001375	Mattina et al., 2003

Average Arsenic uptake factor in leafy crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.00666±0.00982

Table H.9-2 Arsenic field studies on exposed crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field-fly ash - pot	8.8	9.5	tomato	0.03	0.1	0.01	0.059	0.0006	0.00075	Furr et al. 1978
field		6.04	bottle gourd			0.00397	0.126	0.0005	0.000625	Huang et al. 2006
field		6.04	cauliflower			0.00873	0.126	0.0011	0.001375	Huang et al. 2006
field		6.04	celery			0.05873	0.126	0.0074	0.00925	Huang et al. 2006
field		6.04	cowpea			0.00272	0.257	0.0007	0.000875	Huang et al. 2006
field		6.04	eggplant			0.00822	0.073	0.0006	0.00075	Huang et al. 2006
field		6.04	onion			0.0088	0.125	0.0011	0.001375	Huang et al. 2006
field		6.04	towel gourd			0.00397	0.126	0.0005	0.000625	Huang et al. 2006
field			bean			0.27	0.111	0.02997	0.037463	Huq and Naidu 2005
field			cauliflower			0.84	0.126	0.10584	0.1323	Huq and Naidu 2005
field			tomato			0.55	0.059	0.03245	0.040563	Huq and Naidu 2005
mining, smelting-field		446.64	capsicum		0.75	0.0017	0.074	0.00013	0.000163	Li et al., 2006
mining, smelting-field		446.64	cucumber		0.49	0.0011	0.039	0.000043	5.38E-05	Li et al., 2006
mining, smelting-field		446.64	eggplant		0.45	0.001	0.073	0.000074	9.25E-05	Li et al., 2006
field		5.54	broccoli		0.59	0.1065	0.126	0.013419	0.016773	Liu et al. 2006
field		6.48	cucumber		0.53	0.08179	0.039	0.00319	0.003987	Liu et al. 2006
field		6.01	Eggplant		0.98	0.16306	0.073	0.011903	0.014879	Liu et al. 2006
field		6.01	kidney bean		2.98	0.49584	0.111	0.055038	0.068798	Liu et al. 2006
field		6.01	pepper		0.39	0.06489	0.126	0.008176	0.01022	Liu et al. 2006
field		6.01	tomato		0.46	0.07654	0.059	0.004516	0.005645	Liu et al. 2006
air dep, mine waste, poll. Water		459.02	capsicum		1.3		0.074	0.00021	0.000263	Liu et al., (2005)
air dep, mine waste, poll. Water	96.92	459.02	string bean	0.54	1.33	0.0029	0.111	0.00032	0.0004	Liu et al., 2005

Average Arsenic uptake factor in exposed crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0158±0.0313

Table H.9-3 Arsenic field studies on protected crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
25% mine waste - greenhouse	23.3	187	bush bean	0.184	0.304	0.099	0.00016	0.0002	Cobb et al., 2000
field-fly ash - pot	8.8	9.5	corn	0.1	0.2	0.895	0.02	0.025	Furr et al. 1978
field			cowpea			0.257	0.03341	0.041763	Huq and Naidu 2005
field			garlic			0.222	0.12654	0.158175	Huq and Naidu 2005
field			pea			0.257	0.21331	0.266638	Huq and Naidu 2005
field			pumpkin			0.222	0.03108	0.03885	Huq and Naidu 2005
mining, smelting-field		446.64	pumpkin		0.5	0.082	0.000092	0.000115	Li et al., 2006
air dep, mine waste, poll. Water		459.02	corn		0.21	0.261	0.00012	0.00015	Liu et al., 2005

Average Arsenic uptake factor in protected crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0664±0.0962

Table H.9-4 Arsenic field studies on root crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conversion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field-ground water		13.3 (4-14)	potato		0.8	0.0602	0.222	0.013364	0.016706	Alam et al. (2003)
25% mine waste - greenhouse	23.3	187	radish	0.593	2.94	0.01572	0.047	0.00075	0.000938	Cobb et al., 2000
field-fly ash - pot	8.8	9.5	carrot (peeled)	0.05	0.2	0.02	0.118	0.002	0.0025	Furr et al. 1978
field-fly ash - pot	8.8	9.5	Onion (peeled)	0.1	0.3	0.03	0.125	0.004	0.005	Furr et al. 1978
field-fly ash - pot	8.8	9.5	Potato (peeled)	0.1	0.1	0.01	0.222	0.002	0.0025	Furr et al. 1978
field		6.04	garlic			0.0245	0.2	0.0049	0.006125	Huang et al. 2006
field		6.04	radish			0.0285	0.2	0.0057	0.007125	Huang et al. 2006
field		6.04	taro			0.0165	0.2	0.0033	0.004125	Huang et al. 2006
field			carrot			0.23	0.118	0.02714	0.033925	Huq and Naidu 2005
field			radish			0.18	0.2	0.036	0.045	Huq and Naidu 2005
wood preserve. Factory-field	3.4	17.9	carrot (unpeeled)	0.032	0.042	0.0023	0.118	0.00027	0.000338	Larsen et al., 1992
wood preserve. Factory-field	3.4	17.9	potato (unpeeled)	0.037	0.077	0.0043	0.222	0.00095	0.001188	Larsen et al., 1992
field		5.54	carrot		0.15	0.02708	0.118	0.003195	0.003994	Liu et al. 2006
field		6.01	radish		0.22	0.03661	0.2	0.007321	0.009151	Liu et al. 2006
landfill-field		27	carrot (unpeeled)		0.17	0.0063	0.106	0.00067	0.000838	Samsoe-Petersen et al., (2002)
landfill-field		27	potato (unpeeled)		0.127	0.0047	0.094	0.00044	0.00055	Samsoe-Petersen et al., 2002
landfill-field		27	radish		0.27	0.01	0.059	0.00059	0.000738	Samsoe-Petersen et al., 2002

Average Arsenic uptake factor in root crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.00828±0.0129

Table H.10-1 Cadmium field studies on leafy crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field	0.69	1.6	amaranth	0.81	3.85	2.406	0.08	0.1925	0.2406	Hu and Ding (2009)
field		0.16	amaranth		0.16	1.000	0.08	0.0800	0.1000	Liu et al. 2006
indust. Poll. Depo. - field		12	amaranthus		5.66	0.470	0.08	0.0380	0.0475	Pandey and Pandey, (2009)
Indust. sewage wastes - field	0.5	22	amaranthus	0.14	1.1	0.050	0.08	0.0040	0.0050	Srikanth et al., (1991)
field-wastewater	0.12	0.87	basil	0.16	0.6	0.690	0.08	0.0550	0.0688	Shariatpanahi and Anderson (1986)
field		4.4	cabbage		0.3	0.068	0.08	0.0055	0.0068	Chumbley and Unwin (1982)
sewage sludge - pots		23.22	cabbage		1.77	0.076	0.08	0.0061	0.0076	Jackson & Alloway, (1991)
mining, smelting-field		7.43	cabbage		0.71	0.096	0.08	0.0077	0.0096	Li et al., 2006
mining, smelting-field		7.43	cabbage		1.29	0.170	0.08	0.0130	0.0163	Li et al., 2006
field		0.16	cabbage		0.076	0.475	0.08	0.0380	0.0475	Liu et al. 2006
sewage sludge - field		10.5	cabbage		2.1	0.200	0.08	0.0200	0.0250	Muntau et al., (1987)
Indust. sewage wastes - field	0.5	22	cabbage	0.02	2.88	0.130	0.078	0.0100	0.0125	Srikanth et al., 1991
field - smelter	0.108	4.99	cabbage				0.052	0.1740	0.2175	Zheng et al. (2007a)a
field		1.6	celery		3.57	2.231	0.08	0.1785	0.2231	Hu and Ding 2009
field		0.16	celery		0.1	0.625	0.08	0.0500	0.0625	Liu et al. 2006
field - smelter	0.108	12.5	celery				0.058	0.1310	0.16375	Zheng et al. 2007a
mining, smelting-field		7.43	Chinese cabbage		1.31	0.180	0.08	0.0130	0.0163	Li et al., 2006
field		0.16	Chinese cabbage		0.2	1.250	0.08	0.1000	0.1250	Liu et al. 2006
field		0.515	Chinese cabbage		0.2625	0.510	0.08	0.0408	0.0510	Wang et al. (2006)
field - smelter	0.108	22.8	Chinese cabbage				0.055	0.1280	0.16	Zheng et al. 2007a
field		0.16	Chinese chive		0.12	0.750	0.08	0.0600	0.0750	Liu et al. 2006
sewage sludge-field-grnhs		2.55	chinese leek		0.9	0.350	0.089	0.0310	0.0388	Yang et al., (2009)
field-wastewater	0.12	0.87	garden cress	0.1	0.6	0.690	0.08	0.0550	0.0688	Shariatpanahi and Anderson 1986

Table H.10-1 Cadmium field studies on leafy crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field - smelter	0.108	43.4	green onion				0.085	0.0440	0.055	Zheng et al. 2007a
field		0.17	leek		0.055	0.324	0.08	0.0259	0.0324	Liu et al. 2006
field - smelter	0.108	39.2	leek			2.250	0.08	0.1800	0.2250	Zheng et al. 2007a
field		7.8	lettuce		4.2	0.538	0.05	0.0269	0.0337	Chumbley and Unwin 1982
25% mine waste - greenhouse	1.38	6.06	lettuce	1.61	5.37	0.890	0.045	0.0400	0.0500	Cobb et al., 2000
Env. contam. Soil 1a - potted		1.8	lettuce		2.5	1.400	0.049	0.0686	0.0858	Crews & Davies, (1985)
Env. contam. Soil 1b - potted		2.2	lettuce		7.8	3.500	0.049	0.1715	0.2144	Crews & Davies, 1985
Env. contam. Soil 2 - potted		4.5	lettuce		11.8	2.600	0.049	0.1274	0.1593	Crews & Davies, 1985
Env. contam. Soil 3 - potted		5.5	lettuce		20.5	3.700	0.049	0.1813	0.2266	Crews & Davies, 1985
field	0.69	1.6	lettuce	1.49	4.19	2.619	0.05	0.1309	0.1637	Hu and Ding 2009
fertilizer	0.53	0.6-0.86	lettuce				0.05	0.1950	0.2438	Huang et al. (2003)
fertilizer in field			lettuce				0.05	0.3199	0.3998	Huang et al. (2004)
sewage sludge - pots		23.22	lettuce		10.57	0.460	0.05	0.0230	0.0288	Jackson & Alloway, 1991
Env polluted soil - field		1	lettuce		2.6	2.600	0.049	0.1274	0.1593	Mattina et al., 2003
sewage sludge-field		2.2	lettuce		2.8	1.300	0.05	0.0650	0.0813	Preer et al., (1995)
smelter area - urban gardens	0.8	12.6	lettuce	0.41	7.55	0.600	0.049	0.0294	0.0368	Pruvot et al., (2006)
landfill-field		2.4	lettuce		0.552	0.230	0.05	0.0115	0.0144	Samsoe-Petersen et al., 2002
moderate urban poll -field		0.56	lettuce		0.21	0.400	0.05	0.0200	0.0250	Samsoe-Petersen et al., 2002
fertilizer-field	ND	0.311	lettuce	ND	0.06	0.200	0.05	0.0100	0.0125	(Schroeder and Balassa, 1963)
fertilizer-field	ND	0.311	lettuce	ND	0.5	1.600	0.045	0.0720	0.0900	Schroeder & Balassa, 1963
urban gardens-field-to-grnhs	0.08	3.28	lettuce	0.65	1.73	0.760	0.045	0.0342	0.0428	Sterrett et al., (1996)
field - smelter	0.108	4.99	lettuce				0.042	0.2030	0.25375	Zheng et al. 2007
field-wastewater	0.12	0.87	mint	0.11	0.7	0.800	0.08	0.0640	0.0800	Shariatpanahi and Anderson 1986
field - smelter	0.108	20.1	mustard				0.071	0.0870	0.10875	Zheng et al. 2007
field		1.6	pakchoi		2.53	1.581	0.08	0.1265	0.1581	Hu and Ding 2009
field		0.16	pakchoi		0.11	0.688	0.08	0.0550	0.0688	Liu et al. 2006

Table H.10-1 Cadmium field studies on leafy crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field		0.515	Pakchoi		0.275	0.534	0.08	0.0427	0.0534	Wang et al. 2006
field		15.8	Pakchoi		0.21	0.090	0.08	0.0072	0.0090	Yan et al. (2007)
sewage sludge-field-greenhouse		2.55	pakchoi		1.25	0.490	0.076	0.0370	0.0463	Yang et al., 2009
field (industrial sewage irrigation)		2.69	palak (spinach)		1.5	0.560	0.08	0.0450	0.0563	Kumar Sharma et al., 2007
field (industrial sewage irrigation)		2.26	palak (spinach)		2.1	0.930	0.08	0.0740	0.0925	Kumar Sharma et al., 2007
field (industrial sewage irrigation)		2.8	palak (spinach)		2.85	1.000	0.08	0.0800	0.1000	Kumar Sharma et al., 2007
pot	0.167	30.5	Radish	0.388	8.78	0.288	0.08	0.0230	0.0288	Mathe-Gaspar and Anton 2002
pot	0.167	30.5	Radish	0.448	9.05	0.297	0.08	0.0237	0.0297	Mathe-Gaspar and Anton 2002
flooded gardens		1.31	sorrel		0.115	0.088	0.08	0.0070	0.0088	Sipter et al. (2008)
non-flooded gardens		0.43	sorrel		0.101	0.235	0.08	0.0188	0.0235	Sipter et al. 2008
field		4.6	spinach		4.6	1.000	0.08	0.0800	0.1000	Chumbley and Unwin 1982
high-Cd fertilizer - greenhouse	0.25	0.2625	spinach	1.48	2.18	8.300	0.08	0.6600	0.8250	He and Singh (1994)
high-Cd fertilizer - greenhouse	0.25	0.2625	spinach	2.32	2.85	10.860	0.08	0.8700	1.0875	He and Singh 1994
low-Cd fertilizer - greenhouse	0.25	0.2527	spinach	1.48	1.74	6.890	0.08	0.5500	0.6875	He and Singh 1994
low-Cd fertilizer - greenhouse	0.25	0.2527	spinach	2.32	2.58	10.210	0.08	0.8200	1.0250	He and Singh 1994
sewage sludge-field	0.48	5.32	spinach	0.94	12.76	1.991	0.08	0.1600	0.2000	Hooda et al., 1997
sewage sludge-field	1.6	4.3	spinach	0.01	0.14	0.030	0.08	0.0030	0.0038	Jamali et al., 2007
mining, smelting-field		7.43	spinach		1.06	0.140	0.08	0.0110	0.0138	Li et al., 2006
field (sewage-fed lake irrigation)			Spinach			2.500	0.08	0.2000	0.2500	Lokeshwari and Chandrappa 2006
Env polluted soil - field		0.7	spinach		5.3	7.600	0.093	0.7000	0.8750	Mattina et al., 2003
indust. Poll. Depo. - field		12	spinach		5.84	0.490	0.08	0.0390	0.0488	Pandey and Pandey, 2009

Table H.10-1 Cadmium field studies on leafy crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
Indust. sewage wastes - field	0.5	22	spinach	0.13	6.4	0.290	0.086	0.0250	0.0313	Srikanth et al., 1991
field - smelter	0.108	43.4	spinach				0.088	0.0980	0.1225	Zheng et al. 2007
field		9.3	spring greens		1.1	0.118	0.08	0.0095	0.0118	Chumbley and Unwin 1982
sewage sludge - chamber	0.9	8.4	Swiss chard	2.2	11.2	1.300	0.08	0.1000	0.1250	Mahler et al., 1987
sewage sludge + limed - chamber	0.9	8.4	Swiss chard	1.7	8.4	1.000	0.08	0.0800	0.1000	Mahler et al., 1987
fertilizer-field greenhouse	0.07	1.13	Swiss chard	0.26	1.61	1.400	0.08	0.1000	0.1250	Mulla et al., (1980)
drilling fluid-greenhouse	0.6	19.4	swiss chard	1.5	26.9	1.400	0.08	0.1000	0.1250	Nelson et al., (1984)
sewage sludge-field		2.2	Swiss chard		3.15	1.400	0.08	0.1000	0.1250	Preer et al., 1995
field-wastewater	0.12	0.87	tarragon	0.14	0.05	0.060	0.08	0.0046	0.0058	Shariatpanahi and Anderson 1986
field		0.515	Water spinach		0.3625	0.704	0.08	0.0563	0.0704	Wang et al. 2006
field survey						0.507	0.08	0.0406	0.0507	Cambra et al. 1999

Average cadmium uptake factor in leafy crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.139±0.214

Table H.10-2 Cadmium field studies on exposed crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt mg/kg	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field - smelter	0.108	39.2	aubergine			0.513	0.081	0.0416	0.0519	Zheng et al. 2007a
indust. sewage-field-Egypt	ND	28	bell pepper		0.05	0.002	0.074	0.0001	0.0001	Gorbunov et al., 2003
field - smelter	0.108	20.1	bitter melon				0.066	0.0050	0.00625	Zheng et al. 2007a
landfill-field		2	blackberry					0.0025	0.0031	Samsoe-Petersen et al., 2002
field		0.17	broccoli		0.048	0.282	0.126	0.0356	0.0445	Liu et al. 2006
mining, smelting-field		7.43	capsicum		0.41	0.055	0.074	0.0040	0.0050	Li et al., 2006
air dep, mine waste, poll. Water		6.77	capsicum		1.37	0.200	0.074	0.0150	0.0188	Liu et al., 2005
field - smelter	0.108	39.2	capsicum			0.258	0.066	0.0170	0.0213	Zheng et al. 2007a
field		3.5	cauliflower		0.7	0.200	0.126	0.0252	0.0315	Chumbley and Unwin 1982
indust. sewage-field-Egypt	ND	28	cucumber		0.06	0.002	0.039	0.0001	0.0001	Gorbunov et al., 2003
mining, smelting-field		7.43	cucumber		0.66	0.089	0.039	0.0035	0.0044	Li et al., 2006
field		0.16	cucumber		0.059	0.369	0.039	0.0144	0.0180	Liu et al. 2006
sewage sludge-field-grnhs		2.55	cucumber		0.2	0.080	0.04	0.0031	0.0039	Yang et al., 2009
mining, smelting-field		7.43	eggplant		0.4	0.054	0.073	0.0039	0.0049	Li et al., 2006
field		0.16	Eggplant		0.16	1.000	0.073	0.0730	0.0913	Liu et al. 2006
indust. Poll. Depo. - field		12	eggplant		4.18	0.350	0.073	0.0260	0.0325	Pandey and Pandey, 2009
field		0.515	Eggplant		0.3	0.638	0.073	0.0466	0.0583	Wang et al. 2006
indust. sewage-field-Egypt	ND	28	fig		0.015	0.001	0.126	0.0001	0.0001	Gorbunov et al., 2003
sewage sludge-field	1.6	4.3	Indian squash	0.08	0.24	0.060	0.082	0.0050	0.0063	Jamali et al., (2007)
field		0.16	kidney bean		0.036	0.225	0.111	0.0250	0.0312	Liu et al. 2006
field-wastewater	0.12	0.87	leek	0.14	0.5	0.570	0.12	0.0690	0.0863	Shariatpanahi and Anderson 1986
indust. sewage-field-Egypt	ND	28	olive		0.03	0.001	0.126	0.0001	0.0001	Gorbunov et al., 2003
landfill-field		2	pear					0.0034	0.0043	Samsoe-Petersen et al., 2002
sewage sludge-field			pepper				0.0408	0.0290	0.0362	Giordano et al., (1979)
field		0.16	pepper		0.15	0.938	0.126	0.1181	0.1477	Liu et al. 2006
field survey			peppers			0.053	0.126	0.0066	0.0083	Cambra et al. (1999)
landfill-field		2	plum					0.0006	0.0008	Samsoe-Petersen et al., 2002

Table H.10-2 Cadmium field studies on exposed crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt mg/kg	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
sewage sludge-field			squash				0.082	0.0098	0.0123	Giordano et al., 1979
flooded gardens		1.31	squash		0.033	0.025	0.082	0.0021	0.0026	Sipter et al. 2008
non-flooded gardens		0.43	squash		0.005	0.012	0.082	0.0010	0.0012	Sipter et al. 2008
air dep, mine waste, poll. Water	2.08	6.77	string bean	0.21	0.67	0.099	0.111	0.0110	0.0138	Liu et al., 2005
25% mine waste - greenhouse	1.38	6.06	tomato	0.523	0.704	0.120	0.065	0.0078	0.0098	Cobb et al., 2000
field		0.15	tomato		0.11	0.733	0.059	0.0433	0.0541	Liu et al. 2006
indust. Poll. Depo. - field		12	tomato		4.96	0.410	0.059	0.0240	0.0300	Pandey and Pandey, 2009
smelter area - urban gardens	0.8	12.6	tomato	0.15	1.23	0.098	0.065	0.0063	0.0079	Pruvot et al., 2006
flooded gardens		1.31	tomato		0.06	0.046	0.059	0.0027	0.0034	Sipter et al. 2008
non-flooded gardens		0.43	tomato		0.008	0.019	0.059	0.0011	0.0014	Sipter et al. 2008
smelter contam - field	0.08	4.4	tomato		0.43	0.098	0.065	0.0064	0.0080	Tomov & Alandjiyski, (2006)
sewage sludge-field-grnhs		2.55	tomato		0.2	0.080	0.033	0.0026	0.0033	Yang et al., 2009
field - smelter	0.11	43.4	tomato				0.056	0.0030	0.00375	Zheng et al. 2007a
field		0.515	Towel gourd		0.0976	0.189	0.082	0.0155	0.0194	Wang et al. 2006

Average cadmium uptake factor in exposed crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0216±0.0304

Table H.10-3 Cadmium field studies on protected crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant /wet w soil	References
flooded gardens		1.31	bean		0.02	0.01527	0.111	0.001695	0.0021	Sipter et al. 2008
non-flooded gardens		0.43	bean		0.01	0.02326	0.111	0.002581	0.0032	Sipter et al. 2008
indust. sewage-field-Egypt	ND	28	bean (spot)		0.28	0.01	0.111	0.001	0.0013	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	28	bean (white)		0.26	0.009	0.111	0.001	0.0013	Gorbunov et al., 2003
sewage sludge-pot-field		4.6	beans		0.27	0.06	0.222	0.013	0.0163	Sauerbeck, 1991
field survey			broad beans			0.0108	0.126	0.001361	0.0017	Cambra et al. 1999
25% mine waste - grhs	1.38	6.06	bush bean	0.145	0.01	0.0017	0.099	0.00017	0.0002	Cobb et al., 2000
sewage sludge-field			cantelope				0.06	0.0192	0.0240	Giordano et al., 1979
sewage sludge-field	1.6	4.3	cluster beans	0.04	0.2	0.05	0.111	0.005	0.0063	Jamali et al., 2007
field	0.26	25.3889	corn		0.2	0.00788	0.261	0.002056	0.0026	Bi et al. (2006)
air dep, mine waste, poll. Water		6.77	corn		0.47	0.069	0.261	0.018	0.0225	Liu et al., 2005
indust. sewage-field	0.072	3.72	corn	0.002	0.23	0.062	0.895	0.055	0.0688	Nan et al., (2002)
smelter area - ag field	0.4	8.1	corn	0.07	0.18	0.022	0.273	0.0062	0.0078	Pruvot et al., 2006
field		0.515	Cowpea		0.02724	0.05289	0.257	0.013592	0.0170	Wang et al. 2006
field - smelter	0.108	43.4	cowpea				0.097	0.004	0.005	Zheng et al. 2007a
landfill-field		2	green bean		0.098	0.041	0.027	0.0011	0.0014	Samsoe-Petersen et al., 2002
moderate urban poll -field		0.56	green bean		0.009	0.02	0.111	0.002	0.0025	Samsoe-Petersen et al., 2002
landfill-field		2	hazelnut					0.004	0.0050	Samsoe-Petersen et al., 2002
field - smelter	0.108	39.2	kidney bean			0.119	0.103	0.012257	0.0153	Zheng et al. 2007a
fertilizer-field	ND	0.311	onion	ND	0.024	0.08	0.125	0.01	0.0125	Schroeder & Balassa, 1963
fertilizer-field	ND	0.311	pea	ND	0.04	0.1	0.257	0.03	0.0375	Schroeder & Balassa, 1963
sewage sludge-field	1.6	4.3	peas	0.075	0.2	0.05	0.257	0.01	0.0125	Jamali et al., 2007
sewage sludge-pot-field		4.6	peas		0.2	0.04	0.257	0.01	0.0125	Sauerbeck, 1991
mining, smelting-field		7.43	pumpkin		0.46	0.062	0.082	0.0051	0.0064	Li et al., 2006
field - smelter	0.108	43.4	pumpkin				0.065	0.001	0.001	Zheng et al. 2007a
fertilizer-field	ND	0.311	string bean	ND	0.015	0.05	0.111	0.01	0.0125	Schroeder & Balassa, 1963
field		7.8	sweet corn		1.5	0.19231	0.261	0.050192	0.0627	Chumbley and Unwin 1982

Average cadmium uptake factor in protected crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0134±0.0175

Table H.10-4 Cadmium field studies on root crops.

Study Type	soil conc bcgd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bcgd(T) dry wt (mg/kg)	tissue conc contam(C) dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
fertilizer-field	ND	0.311	beet	ND	0.045	0.100	0.2	0.0300	0.0375	Schroeder & Balassa, 1963
field		6.5	beetroot		2	0.308	0.222	0.0683	0.0854	Chumbley and Unwin 1982
smelter - field - home gardens		40.6	carrot		4.4	0.110	0.118	0.0130	0.0163	Chaney et al., (1988)
sewage sludge-field	0.48	5.32	carrot	0.63	1.71	0.350	0.118	0.0410	0.0513	Hooda et al., 1997
field		0.17	carrot		0.085	0.500	0.118	0.0590	0.0738	Liu et al. 2006
indust. Poll. Depo. - field		12	carrot		2.06	0.170	0.118	0.0200	0.0250	Pandey and Pandey, 2009
smelter area - urban gardens	0.8	12.6	carrot	0.085	1.53	0.120	0.118	0.0140	0.0175	Pruvot et al., 2006
fertilizer-field	ND	0.311	carrot	ND	0.068	0.200	0.118	0.0300	0.0375	Schroeder & Balassa, 1963
flooded gardens		1.31	carrot		0.13	0.099	0.118	0.0117	0.0146	Sipter et al. 2008
non-flooded gardens		0.43	carrot		0.068	0.158	0.118	0.0187	0.0233	Sipter et al. 2008
contam-irrig. water - greenhouse		3.6	carrot		1.22	0.340	0.135	0.0460	0.0575	Zheng et al., (2008)
sewage sludge-field-greenhouse		2.55	carrot		0.7	0.270	0.11	0.0300	0.0375	Yang et al., 2009
field - smelter	0.108	39.2	carrot			0.752	0.088	0.0662	0.0827	Zheng et al. 2007a
high-Cd fertilizer - greenhouse	0.25	0.2625	carrot	0.115	0.145	0.550	0.118	0.0650	0.0813	He and Singh 1994
high-Cd fertilizer - greenhouse	0.25	0.2625	carrot	0.125	0.165	0.630	0.118	0.0740	0.0925	He and Singh 1994
low-Cd fertilizer - greenhouse	0.25	0.2527	carrot	0.115	0.135	0.530	0.118	0.0630	0.0788	He and Singh 1994
low-Cd fertilizer - greenhouse	0.25	0.2527	carrot	0.125	0.15	0.590	0.118	0.0700	0.0875	He and Singh 1994
fertilizers w/ Cd		0.3	carrot (unpeeled)		0.25	0.800	0.11	0.0900	0.1125	Jansson and Oborn, (2000)
landfill-field		2.4	carrot (unpeeled)		0.26	0.110	0.127	0.0140	0.0175	Samsoe-Petersen et al., 2002
moderate urban poll -field		0.56	carrot (unpeeled)		0.12	0.200	0.118	0.0300	0.0375	Samsoe-Petersen et al., 2002
sewage sludge-pot-field		4.6	carrots		0.9	0.200	0.118	0.0200	0.0250	Sauerbeck, 1991
field survey			chard			0.519	0.2	0.1038	0.1298	Cambra et al. 1999
indust. sewage-field-Egypt	ND	28	garlic		0.21	0.008	0.125	0.0009	0.0011	Gorbunov et al., 2003
smelter area - urban gardens	0.8	12.6	leek	0.14	1.58	0.130	0.146	0.0180	0.0225	Pruvot et al., 2006
field		3.1	leeks		0.8	0.258	0.2	0.0516	0.0645	Chumbley and Unwin 1982
indust. sewage-field-Egypt	ND	28	onion		0.27	0.010	0.125	0.0010	0.0013	Gorbunov et al., 2003
field-wastewater	0.12	0.87	onion	0.12	0.3	0.340	0.125	0.0400	0.0500	Shariatpanahi and Anderson 1986
flooded gardens		1.31	onion		0.07	0.053	0.125	0.0067	0.0083	Sipter et al. 2008
non-flooded gardens		0.43	onion		0.056	0.130	0.125	0.0163	0.0203	Sipter et al. 2008

Table H.10-4 Cadmium field studies on root crops.

Study Type	soil conc bcgd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bcgd(T) dry wt (mg/kg)	tissue conc contam(C) dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field survey			onions			0.105	0.125	0.0132	0.0164	Cambra et al. 1999
fertilizer-field	ND	0.311	parsnip	0.15	0.7	2.200	0.2	0.5000	0.6250	Schroeder & Balassa, 1963
smelter - field - home gardens		13.2	potato		3.6	0.270	0.202	0.7300	0.9125	Chaney et al., 1988
field		10.8	potato		0.6	0.056	0.222	0.0123	0.0154	Chumbley and Unwin 1982
smelter flue-dust	0.3	106.5	potato	0.16	1.67	0.016	0.222	0.0035	0.0044	Dudka et al. 1996
smelter flue-dust	0.3	54.4	potato	0.16	2.12	0.039	0.222	0.0087	0.0108	Dudka et al. 1996
smelter flue-dust	0.3	7.1	potato	0.16	0.53	0.075	0.222	0.0166	0.0207	Dudka et al. 1996
smelter flue-dust	0.3	3.2	potato	0.16	0.42	0.131	0.222	0.0291	0.0364	Dudka et al. 1996
smelter area - ag field	0.4	8.1	potato	0.3	0.45	0.056	0.202	0.0110	0.0138	Pruvot et al., 2006
smelter area - urban gardens	0.8	12.6	potato	0.05	0.54	0.043	0.202	0.0087	0.0109	Pruvot et al., 2006
fertilizer-field	ND	0.311	potato	ND	0.015	0.050	0.222	0.0100	0.0125	Schroeder & Balassa, 1963
smelter contam - field	0.08	4.4	potato		0.097	0.022	0.202	0.0044	0.0055	Tomov & Alandjiyski, 2006
sewage sludge - pots		23.22	potato (peeled)		0.3	0.013	0.222	0.0029	0.0036	Jackson & Alloway, 1991
sewage sludge-field		2.77	potato (peeled)		0.07	0.030	0.218	0.0055	0.0069	Smith (1994)
landfill-field		2.4	potato (unpeeled)		0.089	0.037	0.135	0.0050	0.0063	Samsoe-Petersen et al., 2002
moderate urban poll -field		0.56	potato(unpeeled)		0.05	0.090	0.222	0.0200	0.0250	Samsoe-Petersen et al., 2002
field		2.7	radish		1.7	0.630	0.222	0.1398	0.1747	Chumbley and Unwin 1982
25% mine waste - greenhouse	1.38	6.06	radish	0.01	2.31	0.380	0.047	0.0180	0.0225	Cobb et al., 2000
indust. sewage-field-Egypt	ND	28	radish		0.28	0.010	0.085	0.0009	0.0011	Gorbunov et al., 2003
field		0.16	radish		0.083	0.519	0.2	0.1038	0.1297	Liu et al. 2006
field (sewage-fed lake irrigation)			Radish			1.600	0.2	0.3200	0.4000	Lokeshwari and Chandrappa 2006
indust. Poll. Depo. - field		12	radish		2.61	0.220	0.085	0.0190	0.0238	Pandey and Pandey, 2009
smelter area - urban gardens	0.8	12.6	radish	0	2.12	0.170	0.047	0.0079	0.0099	Pruvot et al., 2006
landfill-field		2.4	radish		0.19	0.080	0.041	0.0033	0.0041	Samsoe-Petersen et al., 2002
moderate urban poll -field		0.56	radish		0.071	0.100	0.085	0.0100	0.0125	Samsoe-Petersen et al., 2002
sewage sludge-pot-field		4.6	radish		1.1	0.200	0.05	0.0100	0.0125	Sauerbeck, 1991
fertilizer-field	ND	0.311	radish	ND	0.1	0.300	0.2	0.0600	0.0750	Schroeder & Balassa, 1963
field-wastewater	0.12	0.87	radish	0.18	0.45	0.520	0.085	0.0400	0.0500	Shariatpanahi and Anderson 1986

Table H.10-4 Cadmium field studies on root crops.

Study Type	soil conc bcgd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bcgd(T) dry wt (mg/kg)	tissue conc contam(C) dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
contam-irrig. water - greenhouse		3.6	radish		1.09	0.300	0.083	0.0250	0.0313	Zheng et al., 2008
sewage sludge-field-greenhouse		2.55	radish		0.5	0.200	0.05	0.0098	0.0123	Yang et al., 2009
field		4.8	salad onions		1	0.208	0.125	0.0260	0.0326	Chumbley and Unwin 1982
fertilizer-field	ND	0.311	turnip	ND	0.15	0.500	0.2	0.1000	0.1250	Schroeder & Balassa, 1963
field - smelter	0.108	39.2	turnip			0.027	0.108	0.0029	0.0036	Zheng et al. 2007a

Average cadmium uptake factor in root crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0683±0.144

Table H.11-1 Lead field studies on leafy crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt mg/kg	tissue conc contam dry wt mg/kg	Uptake factor (contam) dry wt	dry-to-wet wt conversion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
pots -env. chamber	30	300	cabbage		2.4	0.0080	0.08	0.0006	0.00075	Caille et al., 2005
pots -env. chamber	30	300	rape		2.3	0.0080	0.08	0.0006	0.00075	Caille et al., 2005
field		117	cabbage		0.3	0.0026	0.08	0.000205	0.0002564	Chumbley and Unwin 1982
field		155	lettuce		2.3	0.0148	0.05	0.000742	0.0009274	Chumbley and Unwin 1982
field		124	spinach		3.7	0.0298	0.08	0.002387	0.0029839	Chumbley and Unwin 1982
field		214	spring greens		2.3	0.0107	0.08	0.00086	0.0010748	Chumbley and Unwin 1982
field		532	leaf mustard		21	0.0395	0.08	0.003158	0.0039474	Clemente et al. 2005
25% mine waste - grnhs	60.9	3600	lettuce	29.8	227	0.0631	0.045	0.002838	0.0035469	Cobb et al., 2000
Env. contam. Soil 1a - potted - outside		301	lettuce		2	0.0066	0.049	0.000326	0.000407	Crews & Davies, 1985
Env. contam. Soil 1b - potted - outside		169	lettuce		7.7	0.0456	0.049	0.002233	0.0027907	Crews & Davies, 1985
Env. contam. Soil 2 - potted - outside		754	lettuce		5.7	0.0076	0.049	0.00037	0.000463	Crews & Davies, 1985
Env. contam. Soil 3 - potted - outside		850	lettuce		14.3	0.0168	0.049	0.000824	0.0010304	Crews & Davies, 1985
urban gardens-field			cilantro				0.08	0.002	0.0025	Finster et al., 2004
urban gardens-field			collard greens				0.147	0.0004	0.0005	Finster et al., 2004
urban gardens-field			coriander				0.08	0.003	0.00375	Finster et al., 2004
urban gardens-field			ipasote				0.08	0.002	0.0025	Finster et al., 2004
urban gardens-field			lemon balm				0.08	0.001	0.00125	Finster et al., 2004
urban gardens-field			mint				0.08	0.0009	0.001125	Finster et al., 2004
urban gardens-field			rhubarb				0.052	0.00047	0.0005875	Finster et al., 2004
urban gardens-field			Swiss chard				0.089	0.0027	0.003375	Finster et al., 2004
sewage sludge-field	70	259	spinach	0.82	0.95	0.0080	0.08	0.0006	0.00075	Hooda et al., 1997
field	65.9	361	amaranth	2.66	45.7	0.1266	0.08	0.010127	0.0126593	Hu and Ding 2009
field		361	celery		22.1	0.0612	0.08	0.004898	0.0061219	Hu and Ding 2009
field	65.9	361	lettuce	1.14	37.5	0.1039	0.05	0.005194	0.0064924	Hu and Ding 2009
field		361	pakchoi		36.2	0.1003	0.08	0.008022	0.0100277	Hu and Ding 2009

Table H.11-1 Lead field studies on leafy crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt mg/kg	tissue conc contam dry wt mg/kg	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
Pb arsenate - grnhs	60.9	342.3	lettuce	10.2	12.5	0.0400	0.05	0.002	0.0025	Hutchinson et al. 1974
sewage sludge-field	21.1	67.4	spinach	0.33	1.2	0.0200	0.08	0.001	0.00125	Jamali et al., 2007
mining, smelting-field		223.22	cabbage			0.0500	0.08	0.004	0.005	Li et al., 2006
mining, smelting-field		223.22	cabbage			0.0490	0.08	0.0039	0.004875	Li et al., 2006
mining, smelting-field		223.22	Chinese cabbage			0.0780	0.08	0.0062	0.00775	Li et al., 2006
mining, smelting-field		223.22	spinach			0.0700	0.08	0.0056	0.007	Li et al., 2006
field		14.48	amaranth		1.91	0.1319	0.08	0.010552	0.0131906	Liu et al. 2006
field		14.48	cabbage		1	0.0691	0.08	0.005525	0.0069061	Liu et al. 2006
field		14.48	celery		1.76	0.1215	0.08	0.009724	0.0121547	Liu et al. 2006
field		14.48	Chinese cabbage		2.05	0.1416	0.08	0.011326	0.0141575	Liu et al. 2006
field		14.48	Chinese chive		2.53	0.1747	0.08	0.013978	0.0174724	Liu et al. 2006
field		14.48	pakchoi		2.02	0.1395	0.08	0.01116	0.0139503	Liu et al. 2006
pot	18.5	2897	Radish	2.9	94.3	0.0326	0.047	0.00153	0.0019124	Mathe-Gaspar and Anton 2002
pot	18.5	2897	Radish	2.4	272.4	0.0940	0.047	0.004419	0.0055242	Mathe-Gaspar and Anton 2002
sewage sludge - field		775	cabbage		0.31	0.0004	0.08	0.00003	0.0000375	Muntau et al., 1987
drilling fluid-grnhs	17	1131	swiss chard	1.7	9.2	0.0080	0.08	0.0007	0.000875	Nelson et al., 1984
Env. contam. Soil (paint?) - potted - grnhs		2000	collard		8	0.0040	0.147	0.0006	0.00075	Nicklow et al., (1983)
Env. contam. Soil (paint?) - potted - grnhs		2000	kale		7	0.0035	0.173	0.0006	0.00075	Nicklow et al., 1983
Env. contam. Soil (paint?) - potted - grnhs		2000	lettuce		25	0.0125	0.049	0.000613	0.0007656	Nicklow et al., 1983
indust. Poll. Depo. - field		165.85	amaranth us		18.44	0.1100	0.08	0.0088	0.011	Pandey and Pandey, 2009
indust. Poll. Depo. - field		165.85	spinach		19.58	0.1200	0.08	0.0096	0.012	Pandey and Pandey, 2009
sewage sludge-field		98	lettuce			0.0200	0.05	0.001	0.00125	Preer et al., 1995

Table H.11-1 Lead field studies on leafy crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt mg/kg	tissue conc contam dry wt mg/kg	Uptake factor (contam) dry wt	dry-to-wet wt conversion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
sewage sludge-field		98	Swiss chard			0.0300	0.08	0.003	0.00375	Preer et al., 1995
smelter area - urban gardens - field	84	872	lettuce	2.24	6.93	0.0079	0.049	0.000387	0.0004839	Pruvot et al., 2006
landfill-field		1000	lettuce		1.3	0.0013	0.05	0.000065	8.125E-05	Samsoe-Petersen et al., 2002
moderate urban poll -field		130	lettuce		0.25	0.0020	0.05	0.0001	0.000125	Samsoe-Petersen et al., 2002
field-wastewater	0.32	2.04	basil	0.18	0.84	0.4100	0.08	0.033	0.04125	Shariatpanahi and Anderson 1986
field-wastewater	0.32	2.04	garden cress	0.16	0.8	0.3900	0.08	0.031	0.03875	Shariatpanahi and Anderson 1986
field-wastewater	0.32	2.04	mint	0.29	0.78	0.3800	0.08	0.031	0.03875	Shariatpanahi and Anderson 1986
field-wastewater	0.32	2.04	tarragon	0.15	0.68	0.3300	0.08	0.027	0.03375	Shariatpanahi and Anderson 1986
flooded gardens		85.2	sorrel		0.99	0.0116	0.08	0.00093	0.001162	Sipter et al. 2008
non-flooded gardens		27.8	sorrel		0.295	0.0106	0.08	0.000849	0.0010612	Sipter et al. 2008
sewage sludge-field			spinach				0.08	0.00048	0.0006	Sridhara Chary et al., 2008
Indust. sewage wastes - field	3.4	183.5	amaranthus	0.12	12.2	0.0660	0.08	0.0054	0.00675	Srikanth et al., 1991
Indust. sewage wastes - field	3.4	183.5	cabbage	0.64	7.52	0.0410	0.078	0.0032	0.004	Srikanth et al., 1991
Indust. sewage wastes - field	3.4	183.5	spinach	0.05	14.94	0.0810	0.086	0.007	0.00875	Srikanth et al., 1991
urban gardens-field-to-grnhs	12	1601	lettuce	2.22	8.67	0.0080	0.045	0.00036	0.00045	Sterrett et al., 1996
field		71.31	Chinese cabbage		0.65	0.0091	0.08	0.000729	0.0009115	Wang et al. 2006
field		71.31	Pakchoi		0.7625	0.0107	0.08	0.000855	0.0010693	Wang et al. 2006
field		71.31	Water spinach		1.2125	0.0170	0.08	0.00136	0.0017003	Wang et al. 2006
field		400.3	Pakchoi		3.28	0.0680	0.08	0.00544	0.0068	Yan et al. 2007
field - smelter	21.6	319.6	leek			0.2760	0.08	0.02208	0.0276	Zheng et al. 2007a
field - smelter		158	Chinese cabbage				0.055	0.018	0.023	Zheng et al. 2007b
field - smelter		297	green onion				0.085	0.006	0.008	Zheng et al. 2007b
field - smelter		297	spinach				0.088	0.025	0.03	Zheng et al. 2007b

Table H.11-1 Lead field studies on leafy crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt mg/kg	tissue conc contam dry wt mg/kg	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field - smelter		139	celery				0.058	0.016	0.02	Zheng et al. 2007b
field - smelter		111	cabbage				0.052	0.019	0.024	Zheng et al. 2007b
field - smelter		111	lettuce				0.042	0.024	0.03	Zheng et al. 2007b
field - smelter		167	mustard				0.071	0.021	0.026	Zheng et al. 2007b

Average lead uptake factor in leafy crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0077±0.0104

Table H.11-2 Lead field studies on exposed crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Common Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field		12	peach		1.4	0.1167	0.131	0.015283	0.0191042	Basar and Aydmalp (2005)
field		12	peach		2.9	0.2417	0.131	0.031658	0.0395729	Basar and Aydmalp 2005
field		11	peach		0.8	0.0727	0.131	0.009527	0.0119091	Basar and Aydmalp 2005
field		137	cauliflower		2	0.0146	0.126	0.001839	0.0022993	Chumbley and Unwin 1982
indust. sewage-field-Egypt	ND	334	bell pepper		0.4	0.0010	0.074	0.00007	0.0000875	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	334	cucumber		0.3	0.0009	0.039	0.00004	0.00005	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	334	fig		0.6	0.0020	0.225	0.00045	0.0005625	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	334	olive		0.3	0.0009	0.2	0.0002	0.00025	Gorbunov et al., 2003
sewage sludge-field	21.1	67.4	Indian squash	0.33	1.4	0.0200	0.082	0.002	0.0025	Jamali et al., 2007
mining, smelting-field		223.22	capsicum			0.0370	0.074	0.0027	0.003375	Li et al., 2006
mining, smelting-field		223.22	cucumber			0.0460	0.039	0.0018	0.00225	Li et al., 2006
mining, smelting-field		223.22	eggplant			0.0220	0.073	0.0016	0.002	Li et al., 2006
field		14.49	broccoli		0.34	0.0235	0.126	0.002957	0.0036957	Liu et al. 2006
field		14.48	cucumber		1.39	0.0960	0.039	0.003744	0.0046797	Liu et al. 2006
field		14.48	Eggplant		1.3	0.0898	0.073	0.006554	0.0081923	Liu et al. 2006
field		14.48	kidney bean		0.91	0.0628	0.111	0.006976	0.0087198	Liu et al. 2006
field		14.48	pepper		4.25	0.2935	0.126	0.036982	0.0462276	Liu et al. 2006
field		14.47	tomato		5.23	0.3614	0.059	0.021325	0.026656	Liu et al. 2006
air dep, mine waste, poll. Water		751.98	capsicum		4.58	0.0061	0.074	0.00045	0.0005625	Liu et al., 2005
air dep, mine waste, poll. Water	60.49	751.98	string bean	0.84	5.82	0.0077	0.111	0.00086	0.001075	Liu et al., 2005
indust. Poll. Depo. - field		165.85	eggplant		13.15	0.0790	0.073	0.0058	0.00725	Pandey and Pandey, 2009
indust. Poll. Depo. - field		165.85	tomato		15.2	0.0920	0.059	0.0054	0.00675	Pandey and Pandey, 2009
smelter area - urban gardens - field	84	872	tomato	0	1.38	0.0016	0.065	0.0001	0.000125	Pruvot et al., 2006
Kalvebod area		613	blackberry					0.000026	0.0000325	Samsoe-Petersen et al., 2002
Kalvebod area		613	pear					0.000016	0.00002	Samsoe-Petersen et al., 2002
Kalvebod area		613	plum					0.000016	0.00002	Samsoe-Petersen et al., 2002
field-wastewater	0.32	2.04	leek	0.2	0.65	0.3200	0.12	0.038	0.0475	Shariatpanahi and Anderson

Table H.11-2 Lead field studies on exposed crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Common Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver -sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
										1986
flooded gardens		85.2	squash		0.673	0.0079	0.082	0.000648	0.0008097	Sipter et al. 2008
flooded gardens		85.2	tomato		0.48	0.0056	0.059	0.000332	0.0004155	Sipter et al. 2008
non-flooded gardens		27.8	squash		0.079	0.0028	0.082	0.000233	0.0002913	Sipter et al. 2008
non-flooded gardens		27.8	tomato		0.083	0.0030	0.059	0.000176	0.0002202	Sipter et al. 2008
smelter contam - field	22	163	tomato		7.15	0.0440	0.065	0.0029	0.003625	Tomov & Alandjiyski, 2006
field		71.31	Eggplant		0.3973	0.0056	0.073	0.000407	0.0005083	Wang et al. 2006
field		71.31	Towel gourd		0.3415	0.0048	0.082	0.000393	0.0004908	Wang et al. 2006
field - smelter	21.6	319.6	aubergine			0.0240	0.066	0.001584	0.00198	Zheng et al. 2007a
field - smelter	21.6	319.6	capsicum			0.0240	0.081	0.001944	0.00243	Zheng et al. 2007a
field - smelter		297	tomato				0.056	0.002	0.003	Zheng et al. 2007b
field - smelter		167	bitter melon				0.066	0.003	0.004	Zheng et al. 2007b

Average lead uptake factor in exposed crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.00693±0.0124

Table H.11-3 Lead field studies on protected crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Common Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field	50	318.056	corn		1.1	0.0035	0.261	0.000903	0.0011283	Bi et al. 2006
field		156	sweet corn		0.1	0.0006	0.261	0.000167	0.0002091	Chumbley and Unwin 1982
25% mine waste - grnhs	60.9	3600	bush bean	5.53	0	-	0.099	0.00017	0.0002125	Cobb et al., 2000
indust. sewage-field-Egypt	ND	334	bean (spot)		2.2	0.0070	0.894	0.006	0.0075	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	334	bean (white)		0.9	0.0030	0.894	0.003	0.00375	Gorbunov et al., 2003
sewage sludge-field	21.1	67.4	cluster beans	0.104	0.6	0.0090	0.111	0.001	0.00125	Jamali et al., 2007
sewage sludge-field	21.1	67.4	peas	0.22	0.74	0.0100	0.257	0.003	0.00375	Jamali et al., 2007
mining, smelting-field		223.22	pumpkin			0.0470	0.082	0.0039	0.004875	Li et al., 2006
air dep, mine waste, poll. Water		751.98	corn		1.91	0.0025	0.261	0.00066	0.000825	Liu et al., 2005
field (sewage-fed lake irrigation)			Beans			0.2000	0.111	0.0222	0.02775	Lokeshwari and Chandrappa 2006
smelter area - ag field	30	440	corn	0	0.92	0.0021	0.273	0.00057	0.0007125	Pruvot et al., 2006
Kalvebod area		613	hazelnut					0.00073	0.0009125	Samsoe-Petersen et al., 2002
landfill-field		1000	green bean		1.4	0.0014	0.042	0.00006	0.000075	Samsoe-Petersen et al., 2002
moderate urban poll -field		130	green bean		0.18	0.0010	0.111	0.0002	0.00025	Samsoe-Petersen et al., 2002
sewage sludge-pot-field		154	beans			0.0080	0.222	0.002	0.0025	Sauerbeck, 1991
sewage sludge-pot-field		154	peas			0.0010	0.257	0.0003	0.000375	Sauerbeck, 1991
flooded gardens		85.2	bean		0.26	0.0031	0.111	0.000339	0.0004234	Sipter et al. 2008
non-flooded gardens		27.8	bean		0.141	0.0051	0.111	0.000563	0.0007037	Sipter et al. 2008
field		71.31	Cowpea		0.2023	0.0028	0.257	0.000729	0.0009115	Wang et al. 2006
field - smelter	21.6	319.6	kidney bean			0.0320	0.103	0.003296	0.00412	Zheng et al. 2007a
field - smelter		297	cowpea				0.097	0.003	0.004	Zheng et al. 2007b
field - smelter		297	pumpkin				0.065	0.001	0.001	Zheng et al. 2007b

Average lead uptake factor in protected crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.00282±0.00565

Table H.11-4 Lead field studies on root crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Common Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conve r-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field-ground water		28	potato		0.5	0.0179	0.222	0.003974	0.0049673	Alam et al. 2003
salt	40.5	744.5	carrot	0.312	5.754	0.0077	0.118	0.000912	0.00114	Alexander et al. (2006)
salt	40.5	744.5	Onion	1.418	7.458	0.0100	0.125	0.001252	0.0015652	Alexander et al. 2006
smelter - field - home gardens		130	carrot		2.2	0.0169	0.118	0.002	0.0025	Chaney et al., 1988
smelter - field - home gardens		48	potato		2.6	0.0542	0.202	0.01	0.0125	Chaney et al., 1988
field		103	beetroot		0.4	0.0039	0.222	0.000862	0.0010777	Chumbley and Unwin 1982
field		97	leeks		0.8	0.0082	0.2	0.001649	0.0020619	Chumbley and Unwin 1982
field		176	potato		0.2	0.0011	0.222	0.000252	0.0003153	Chumbley and Unwin 1982
field		110	radish		2.9	0.0264	0.222	0.005853	0.0073159	Chumbley and Unwin 1982
field		107	onions		0.6	0.0056	0.125	0.000701	0.0008762	Chumbley and Unwin 1982
25% mine waste - grnhs	60.9	3600	radish	0	92.4	0.0257	0.047	0.0012	0.0015	Cobb et al., 2000
smelter flue-dust	6.8	146.3	potato	0.2	0.2	0.0014	0.222	0.000303	0.0003794	Dudka et al. (1996)
smelter flue-dust	6.8	340	potato	0.2	0.4	0.0012	0.222	0.000261	0.0003265	Dudka et al. 1996
smelter flue-dust	6.8	2202.5	potato	0.2	0.7	0.0003	0.222	7.06E-05	8.82E-05	Dudka et al. 1996
smelter flue-dust	6.8	5452.5	potato	0.2	0.9	0.0002	0.222	3.66E-05	4.58E-05	Dudka et al. 1996
urban gardens-field			carrot				0.118	0.0006	0.00075	Finster et al., (2004)
urban gardens-field			onion				0.125	0.004	0.005	Finster et al., 2004
urban gardens-field			radish				0.047	0.00094	0.001175	Finster et al., 2004
indust. sewage-field-Egypt	ND	334	garlic		1	0.0030	0.387	0.001	0.00125	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	334	onion		1.1	0.0030	0.125	0.0004	0.0005	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	334	radish		2.3	0.0070	0.047	0.0003	0.000375	Gorbunov et al., 2003
sewage sludge-field	70	259	carrot	0.33	0.48	0.0040	0.118	0.0005	0.000625	Hooda et al., 1997
Pb arsenate - grnhs	60.9	342.3	carrot	3.9	13.3	0.0400	0.118	0.005	0.00625	Hutchinson et al. (1974)
Pb arsenate - grnhs	60.9	342.3	onion	10	75.4	0.2000	0.125	0.03	0.0375	Hutchinson et al. 1974
Pb arsenate - grnhs	60.9	342.3	parsnip	7.8	14.8	0.0400	0.209	0.008	0.01	Hutchinson et al. 1974
Pb arsenate - grnhs	60.9	342.3	radish	7.9	27.5	0.0800	0.047	0.004	0.005	Hutchinson et al. 1974
field		14.49	carrot		0.92	0.0635	0.118	0.007492	0.0093651	Liu et al. 2006
field		14.49	leek		0.92	0.0635	0.146	0.00927	0.0115873	Liu et al. 2006
field		14.48	radish		0.47	0.0325	0.047	0.001526	0.0019069	Liu et al. 2006
Env. contam. Soil (paint?) - potted - grnhs		2000	beet		19	0.0095	0.127	0.001	0.00125	Nicklow et al., 1983

Table H.11-4 Lead field studies on root crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Common Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conve r-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
Env. contam. Soil (paint?) - potted - grnhs		2000	carrot		34	0.0170	0.118	0.002	0.0025	Nicklow et al., 1983
Env. contam. Soil (paint?) - potted - grnhs		2000	turnip		22	0.0110	0.085	0.0009	0.001125	Nicklow et al., 1983
indust. Poll. Depo. - field		165.85	carrot		8.16	0.0490	0.118	0.0058	0.00725	Pandey and Pandey, 2009
indust. Poll. Depo. - field		165.85	radish		11.7	0.0710	0.047	0.0033	0.004125	Pandey and Pandey, 2009
smelter area - ag field	30	440	potato	0.099	0.099	0.0002	0.202	0.000045	5.625E-05	Pruvot et al., 2006
smelter area - urban gardens - field	84	872	carrot	0.25	1.17	0.0013	0.118	0.00024	0.0003	Pruvot et al., 2006
smelter area - urban gardens - field	84	872	leek	0.34	2.67	0.0031	0.146	0.00045	0.0005625	Pruvot et al., 2006
smelter area - urban gardens - field	84	872	potato	0	0.15	0.0002	0.202	0.000034	0.0000425	Pruvot et al., 2006
smelter area - urban gardens - field	84	872	radish	0	3.83	0.0044	0.047	0.00021	0.0002625	Pruvot et al., 2006
landfill-field		1000	carrot unp		5.1	0.0051	0.104	0.00053	0.0006625	Samsoe-Petersen et al., 2002
landfill-field		1000	potato unp		2	0.0020	0.113	0.00023	0.0002875	Samsoe-Petersen et al., 2002
landfill-field		1000	radish		7.4	0.0074	0.036	0.00027	0.0003375	Samsoe-Petersen et al., 2002
moderate urban poll -field		130	carrot unp		0.93	0.0070	0.118	0.0009	0.001125	Samsoe-Petersen et al., 2002
moderate urban poll -field		130	potato unp		0.18	0.0010	0.222	0.0003	0.000375	Samsoe-Petersen et al., 2002
moderate urban poll -field		130	radish		1.65	0.0100	0.085	0.001	0.00125	Samsoe-Petersen et al., 2002
sewage sludge-pot-field		154	carrots			0.0030	0.118	0.0004	0.0005	Sauerbeck, 1991
sewage sludge-pot-field		154	radish			0.0200	0.05	0.0009	0.001125	Sauerbeck, 1991
field-wastewater	0.32	2.04	onion	0.22	0.46	0.2300	0.125	0.028	0.035	Shariatpanahi and Anderson 1986
field-wastewater	0.32	2.04	radish	0.28	0.73	0.3600	0.047	0.02	0.025	Shariatpanahi and Anderson 1986
flooded gardens		85.2	carrot		0.81	0.0095	0.118	0.001122	0.0014023	Sipter et al. 2008
flooded gardens		85.2	onion		1.06	0.0124	0.125	0.001555	0.001944	Sipter et al. 2008
non-flooded gardens		27.8	carrot		0.278	0.0100	0.118	0.00118	0.001475	Sipter et al. 2008
non-flooded gardens		27.8	onion		0.13	0.0047	0.125	0.000585	0.0007307	Sipter et al. 2008
smelter contam - field	22	163	potato		2.95	0.0180	0.202	0.0037	0.004625	Tomov & Alandjiyski, 2006
field - smelter	21.6	319.6	carrot			0.0320	0.108	0.003456	0.00432	Zheng et al. 2007a
field - smelter	21.6	319.6	turnip			0.0270	0.088	0.002376	0.00297	Zheng et al. 2007a
field - smelter		167	potato				0.11	0.001	0.001	Zheng et al. 2007b

Average lead uptake factor in root crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.00403±0.0075

Table H.12-1 Mercury field studies on leafy crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
Hgt pots -env. chamber		17.6	cabbage		1.5	0.09	0.08	0.007	0.00875	Caille (2005)
Hgt pots -env. chamber		17.6	rape		1.7	0.09	0.08	0.008	0.01	Caille et al., 2005
field-compost			lettuce				0.05	0.0122355	0.0152944	Cappon 1987
field-compost			spinach				0.08	0.0137064	0.017133	Cappon 1987
field-compost			Swiss chard				0.08	0.01201	0.0150125	Cappon 1987
field		4.77	amaranth		0.27	0.0566038	0.08	0.0045283	0.0056604	Liu et al. 2006
field		4.77	cabbage		0.21	0.0440252	0.08	0.003522	0.0044025	Liu et al. 2006
field		4.77	celery		0.31	0.0649895	0.08	0.0051992	0.006499	Liu et al. 2006
field		4.77	Ch cabbage		0.15	0.0314465	0.08	0.0025157	0.0031447	Liu et al. 2006
field		4.77	Ch chive		0.32	0.067086	0.08	0.0053669	0.0067086	Liu et al. 2006
field		5.5	leek		0.19	0.0345455	0.08	0.0027636	0.0034545	Liu et al. 2006
field		4.77	pakchoi		0.41	0.0859539	0.08	0.0068763	0.0085954	Liu et al. 2006
field-contam fungicide -greenhouse grown	ND	1.64	lettuce		0.173	0.10549	0.05	0.0052745	0.0065931	(MacLean, 1974)
field-contam fungicide -greenhouse grown	ND	7.13	lettuce		0.103	0.01445	0.05	0.0007225	0.0009031	MacLean 1974
sewage sludge - field		2.5	cabbage		0.01	0.004	0.08	0.0003	0.000375	Muntau et al., 1987
field-wastewater	0.06	0.16	basil	0.05	0.08	0.5	0.08	0.04	0.05	Shariatpanahi and Anderson 1986
field-wastewater	0.06	0.16	gard cress	0.04	0.12	0.75	0.08	0.06	0.075	Shariatpanahi and Anderson 1986
field-wastewater	0.06	0.16	mint	0.06	0.08	0.5	0.08	0.04	0.05	Shariatpanahi and Anderson 1986
field-wastewater	0.06	0.16	tarragon	0.04	0.13	0.81	0.08	0.065	0.08125	Shariatpanahi and Anderson 1986
flooded gardens		0.81	sorrel		0.06	0.0740741	0.08	0.0059259	0.0074074	Sipter et al. 2008
field - smelter	0.037	1.28	leek			0.139	0.08	0.01112	0.0139	Zheng et al. 2007a
field - smelter	0.037	0.76	Ch cabbage				0.055	0.016	0.02	Zheng et al. 2007a
field - smelter	0.037	1.5	Grn onion				0.085	0.01	0.0125	Zheng et al. 2007a
field - smelter	0.037	1.5	spinach				0.088	0.005	0.00625	Zheng et al. 2007a
field - smelter	0.037	0.4	celery				0.058	0.01	0.0125	Zheng et al. 2007a
field - smelter	0.037	0.5	cabbage				0.052	0.031	0.03875	Zheng et al. 2007a
field - smelter	0.037	0.5	lettuce				0.042	0.015	0.01875	Zheng et al. 2007a

Average mercury uptake factor in leafy crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0163±0.0202

Table H.12-2 Mercury field studies on exposed crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field survey			peppers			0.00222	0.126	0.0002797	0.0003497	Cambra et al. 1999
field-compost			broccoli				0.126	0.0145385	0.0181731	Cappon 1987
field-compost			cabbage				0.08	0.0120093	0.0150117	Cappon 1987
field-compost			cucmber				0.039	0.0002636	0.0003295	Cappon 1987
field-compost			pepper				0.074	0.0014145	0.0017681	Cappon 1987
field-compost			squash				0.082	0.0016629	0.0020787	Cappon 1987
field-compost			tomato				0.059	0.0036445	0.0045557	Cappon 1987
field		5.5	broccoli		0.12	0.0218182	0.126	0.0027491	0.0034364	Liu et al. 2006
field		4.03	cucumber		0.15	0.0372208	0.039	0.0014516	0.0018145	Liu et al. 2006
field		4.77	Eggplant		0.26	0.0545073	0.073	0.003979	0.0049738	Liu et al. 2006
field		4.77	kidney bean		0.27	0.0566038	0.111	0.006283	0.0078538	Liu et al. 2006
field		4.77	pepper		0.14	0.0293501	0.126	0.0036981	0.0046226	Liu et al. 2006
field		4.77	tomato		0.13	0.0272537	0.059	0.001608	0.00201	Liu et al. 2006
pots - phenyl mercuric acetate	0.08	5.24	tomato	0.034	0.037	0.0071	0.059	0.00042	0.000525	MacLean 1974
field-wastewater	0.06	0.16	leek	0.04	0.1	0.63	0.12	0.075	0.09375	Shariatpanahi and Anderson 1986
flooded gardens		0.81	squash		0.037	0.045679	0.082	0.0037457	0.0046821	Sipter et al. 2008
flooded gardens		0.81	tomato		0.01	0.0123457	0.059	0.0007284	0.0009105	Sipter et al. 2008
field - smelter	0.037	1.28	aubergine			0.003	0.066	0.000198	0.0002475	Zheng et al. 2007a
field - smelter	0.037	1.28	capsicum			0.007	0.081	0.000567	0.0007088	Zheng et al. 2007a
field - smelter	0.037	1.5	tomato				0.056	0.004	0.005	Zheng et al. 2007a
field - smelter	0.037	0.3	bitter melon				0.066	0.016	0.02	Zheng et al. 2007a

Average mercury uptake factor in exposed crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.00855±0.0194

Table H.12-3 Mercury field studies on protected crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field survey			broad beans			0.003506	0.126	0.0004418	0.0005522	Cambra et al. 1999
field-compost			bean				0.111	0.0011126	0.0013907	Cappon 1987
field	0.15	0.38	corn		0.011	0.0289474	0.261	0.0075553	0.0094441	Feng et al. (2006)
Hgt field-smelter-9 sites			brown rice			0.002	0.888	0.002	0.0025	Horvet et al., 2003
Hgt field-smelter-2 sites			brown rice			0.0001	0.888	0.00009	0.0001125	Horvet et al., 2003
Hgt field-clean area-2 sites			brown rice			0.009	0.888	0.008	0.01	Horvet et al., 2003
field		0.21	wheat		0.003	0.0142857	0.875	0.0125	0.015625	Huang et al. (2008)
HgCl2 - pots - chamber	ND		oats	0.009	0.013	0.002	0.917	0.0018	0.00225	John 1972
HgCl2 - pots - chamber	ND		peas	0.001	0.002	0.00033	0.257	0.000085	0.0001063	John 1972
Hgt field-smelter-23 sites		0.1782	corn		0.0061	0.03	0.261	0.0089	0.011125	Li et al., (2008)
pots - phenyl mercuric acetate	0.08	5.24	oats	0.113	0.163	0.031	0.917	0.029	0.03625	MacLean 1974
pots - phenyl mercuric acetate	0.08	5.24	soybeans	0.074	0.076	0.015	0.925	0.013	0.01625	MacLean 1974
flooded gardens		0.81	bean		0.03	0.037037	0.111	0.0041111	0.0051389	Sipter et al. 2008
field - smelter	0.037	1.28	kidney bean			0.067	0.103	0.006901	0.0086263	Zheng et al. 2007a
field - smelter	0.037	1.5	cowpea				0.097	0.001	0.00125	Zheng et al. 2007a

Average mercury uptake factor in protected crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.00804±0.0096

Table H.12-4 Mercury field studies on root crops.

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field-compost			Beet				0.164	0.0104746	0.0130932	Cappon 1987
field-compost			carrot				0.118	0.0036308	0.0045385	Cappon 1987
field-compost			onion				0.125	0.0105478	0.0131847	Cappon 1987
field-compost			radish				0.222	0.0129371	0.0161713	Cappon 1987
field-compost			turnip				0.222	0.0056406	0.0070507	Cappon 1987
HgCl2 - pots - chamber	ND		carrot	0.044	0.053	0.0075	0.118	0.00089	0.0011125	John (1972)
HgCl2 - pots - chamber	ND		radish	0.013	0.026	0.02	0.085	0.0017	0.002125	John 1972
field		5.5	carrot		0.24	0.0436364	0.118	0.0051491	0.0064364	Liu et al. 2006
field		4.77	radish		0.21	0.0440252	0.2	0.008805	0.0110063	Liu et al. 2006
pots - phenyl mercuric acetate	0.08	5.24	carrot	0.086	0.18	0.034	0.118	0.0041	0.005125	MacLean 1974
pots - phenyl mercuric acetate	0.08	5.24	potato	0.047	0.055	0.01	0.222	0.0023	0.002875	MacLean 1974
field-wastewater	0.06	0.16	onion	0.06	0.06	0.38	0.125	0.047	0.05875	Shariatpanahi and Anderson 1986
field-wastewater	0.06	0.16	radish	0.04	0.08	0.5	0.085	0.043	0.05375	Shariatpanahi and Anderson 1986
flooded gardens		0.81	carrot		0.02	0.0246914	0.118	0.0029136	0.003642	Sipter et al. 2008
flooded gardens		0.81	onion		0.02	0.0246914	0.125	0.0030864	0.003858	Sipter et al. 2008
field - smelter	0.037	1.28	carrot			0.044	0.108	0.004752	0.00594	Zheng et al. 2007a
field - smelter	0.037	1.28	turnip			0.034	0.088	0.002992	0.00374	Zheng et al. 2007a
field - smelter	0.037	0.3	potato				0.11	0.002	0.0025	Zheng et al. (2007b)

Average mercury uptake factor in root crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0119±0.0167

Table H.13-1 Nickel field studies on leafy crops

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field (industrial sewage irrigation)		13.37	palak (spinach)		4.2	0.31	0.08	0.02	0.025	Kumar Sharma et al., 2007
field (industrial sewage irrigation)		15.61	palak (spinach)		5.9	0.38	0.08	0.03	0.0375	Kumar Sharma et al., 2007
field (industrial sewage irrigation)		14.52	palak (spinach)		2.6	0.18	0.08	0.02	0.025	Kumar Sharma et al., 2007
indust. Poll. Depo. - field		119.32	amaranthus		9.5	0.08	0.08	0.0064	0.008	Pandey and Pandey, 2009
indust. Poll. Depo. - field		119.32	spinach		10.62	0.089	0.08	0.0071	0.008875	Pandey and Pandey, 2009
landfill-field		49	lettuce		1.23	0.025	0.05	0.00125	0.0015625	Samsoe-Petersen et al., 2002
sewage sludge - field		120	cabbage		24	0.2	0.08	0.02	0.025	Muntau et al., 1987
sewage sludge-field	22.5	51.8	spinach	4.76	9.46	0.178	0.08	0.014	0.0175	Hooda et al., 1997
sewage sludge-field	28.1	34.6	spinach	0.88	1.2	0.03	0.08	0.003	0.00375	Jamali et al., 2007
sewage sludge-field			spinach				0.08	0.0048	0.006	Sridhara Chary et al., (2008)
urban gardens-field-to-greenhouse	10	50.7	lettuce	0.73	1.25	0.024	0.045	0.00108	0.00135	Sterrett et al., 1996

Average nickel uptake factor in leafy crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0145±0.0121

Table H.13-2 Nickel field studies on exposed crops

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field		112	peach		1.5	0.0133929	0.131	0.0017545	0.0021931	Basar and Aydmalp 2005
field		117	peach		1.6	0.0136752	0.131	0.0017915	0.0022393	Basar and Aydmalp 2005
field		122	peach		2	0.0163934	0.131	0.0021475	0.0026844	Basar and Aydmalp 2005
highly contam area		53	blackberry					0.0021	0.002625	Samsoe-Petersen et al., 2002
highly contam area		53	pear					0.0013	0.001625	Samsoe-Petersen et al., 2002
highly contam area		53	plum					0.0007	0.000875	Samsoe-Petersen et al., 2002
indust. Poll. Depo. - field		119.32	eggplant		7.92	0.066	0.073	0.0048	0.006	Pandey and Pandey, 2009
indust. Poll. Depo. - field		119.32	tomato		9.85	0.083	0.059	0.0049	0.006125	Pandey and Pandey, 2009
indust. sewage-field-Egypt	ND	106	bell pepper		0.7	0.007	0.074	0.0005	0.000625	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	106	cucumber		0.43	0.004	0.039	0.0002	0.00025	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	106	fig		1.6	0.02	0.225	0.0045	0.005625	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	106	olive		0.41	0.004	0.2	0.0008	0.001	Gorbunov et al., 2003
sewage sludge-field	28.1	34.6	Indian squash	1.3	2.1	0.06	0.082	0.005	0.00625	Jamali et al., 2007

Average nickel uptake factor in exposed crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.00293±0.00226

Table H.13-3 Nickel field studies on protected crops

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field (sewage-fed lake irrigation)			Beans			0.1	0.111	0.0111	0.013875	Lokeshwari and Chandrappa (2006)
highly contam area		53	hazelnut					0.033	0.04125	Samsoe-Petersen et al., 2002
indust. sewage-field-Egypt	ND	106	bean (spot)		6.9	0.07	0.894	0.06	0.075	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	106	bean (white)		1.9	0.02	0.894	0.02	0.025	Gorbunov et al., 2003
landfill-field		49	green bean		6.37	0.13	0.076	0.0099	0.012375	Samsoe-Petersen et al., 2002
sewage sludge-field	28.1	34.6	cluster beans	1.21	2.1	0.06	0.111	0.007	0.00875	Jamali et al., 2007
sewage sludge-field	28.1	34.6	peas	1.12	1.18	0.03	0.257	0.009	0.01125	Jamali et al., 2007
sewage sludge-pot-field		25	beans			0.3	0.099	0.03	0.0375	Sauerbeck, 1991
sewage sludge-pot-field		25	peas			0.2	0.257	0.04	0.05	Sauerbeck, 1991

Average nickel uptake factor in protected crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0306±0.0224

Table H.13-4 Nickel field studies on root crops

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
indust. Poll. Depo. - field		119.32	carrot		3.65	0.031	0.118	0.0037	0.004625	Pandey and Pandey, 2009
indust. Poll. Depo. - field		119.32	radish		3.98	0.033	0.047	0.0016	0.002	Pandey and Pandey, 2009
indust. sewage-field-Egypt	ND	106	garlic		2.6	0.02	0.125	0.003	0.00375	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	106	onion		3.1	0.03	0.125	0.004	0.005	Gorbunov et al., 2003
indust. sewage-field-Egypt	ND	106	radish		3.8	0.04	0.085	0.003	0.00375	Gorbunov et al., 2003
landfill-field		49	carrot (unpeeled)		1.86	0.038	0.132	0.005	0.00625	Samsoe-Petersen et al., 2002
landfill-field		49	potato (unpeeled)		0.34	0.007	0.185	0.0013	0.001625	Samsoe-Petersen et al., 2002
landfill-field		49	radish		1.57	0.032	0.048	0.0015	0.001875	Samsoe-Petersen et al., 2002
sewage sludge-field	22.5	51.8	carrot	2.17	5.28	0.118	0.118	0.014	0.0175	Hooda et al., (1997)
sewage sludge-pot-field		25	carrots			0.08	0.118	0.009	0.01125	Sauerbeck, 1991
sewage sludge-pot-field		25	radish			0.2	0.05	0.01	0.0125	Sauerbeck, 1991

Average nickel uptake factor in root crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.00638±0.00516

Table H.15-1 Selenium field studies on leafy crops

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field-fly ash	1.5	1.7	cabbage	0.07	0.2	0.1	0.08	0.009	0.01125	Furr et al. 1978
sewage sludge - field		0.4	cabbage		1.1	2.8	0.08	0.2	0.25	Muntau et al., 1987
field-compost			lettuce				0.05	0.008482	0.0106025	Cappon 1987
field-compost			lettuce				0.05	0.010372	0.012965	Cappon 1987
field		9.84	lettuce		19.16	1.94715	0.05	0.0973575	0.1216969	van Mantgem et al. (1996)
field		6.18	lettuce		5.61	0.90777	0.05	0.0453885	0.0567356	van Mantgem et al. 1996
field		15.9	lettuce		13.63	0.85723	0.05	0.0428615	0.0535769	van Mantgem et al. 1996
field		16.83	lettuce		27.9	1.65775	0.05	0.0828875	0.1036094	van Mantgem et al. 1996
field		17.37	lettuce		12.37	0.71215	0.05	0.0356075	0.0445094	van Mantgem et al. 1996
field-compost			spinach				0.08	0.016888	0.02111	Cappon 1987
field-compost			Swiss chard				0.08	0.00957	0.0119625	Cappon 1987

Average selenium uptake factor in leafy crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0587±0.0713

Table H.15-2 Selenium field studies on exposed crops

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field-fly ash-potted soil	0.3	1.2	apple (w/o seeds)	0.01	0.03	0.03	0.159	0.004	0.005	Furr et al. (1979)
field-compost			broccoli				0.126	0.0130125	0.0162656	Cappon 1987
field-fly ash-potted soil	0.3	1.2	cabbage	0.04	2.4	2	0.08	0.2	0.25	Furr et al. 1979
field-compost			cabbage				0.08	0.0216667	0.0270833	Cappon 1987
field-compost			cucmber				0.039	0.0010563	0.0013203	Cappon 1987
field-compost			pepper				0.074	0.0025107	0.0031384	Cappon (1987)
field-compost			squash				0.082	0.0027089	0.0033862	Cappon 1987
field-fly ash-potted soil	0.3	1.2	tomato	0.015	1.5	1.2	0.059	0.07	0.0875	Furr et al. 1979
field-compost			tomato				0.059	0.0099387	0.0124234	Cappon 1987
field-fly ash - pot	1.5	1.7	tomato	0.01	0.02	0.01	0.059	0.007	0.00875	Furr et al. 1978

Average selenium uptake factor in exposed crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0415±0.0776

Table H.15-3 Selenium field studies on protected crops

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field-compost			bean				0.111	0.0070366	0.0087958	Cappon 1987
field-smelter		16.9	brown rice		1.06	0.06	0.888	0.056	0.07	Horvet et al., (2003)
field-fly ash - pot	1.5	1.7	bush bean	0.02	0.07	0.04	0.111	0.005	0.00625	Furr et al. 1978
field-fly ash-potted soil	0.3	1.2	bush bean	0.025	1.3	1.1	0.111	0.1	0.125	Furr et al. 1979
field-fly ash - pot	1.5	1.7	corn	0.02	0.05	0.03	0.895	0.03	0.0375	Furr et al. 1978
field-fly ash-potted soil	0.3	1.2	Japanese millet grain	0.025	1.4	1.1	0.888	1	1.25	Furr et al. 1979
field-fly ash-potted soil			onion		2.3	1.9	0.125	0.2375	0.296875	Furr et al. 1979

Average selenium uptake factor in protected crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.256±0.450

Table H.15-4 Selenium field studies on root crops

Study Type	soil conc bckd (mg/kg)	soil conc contam (mg/kg)	Crop Name	tissue conc bckg dry wt (mg/kg)	tissue conc contam dry wt (mg/kg)	Uptake factor (contam) dry wt	dry-to-wet wt conver-sion factor	Uptake factor (contam) wet wt plant/dw soil	Uptake factor (contam) ww plant/wet w soil	Reference
field-compost			Beet				0.164	0.0098107	0.0122634	Cappon 1987
field-fly ash-potted soil	0.3	1.2	carrot	0.015	1.5	1.3	0.118	0.1	0.125	Furr et al. 1979
field-compost			carrot				0.118	0.0082179	0.0102723	Cappon 1987
field-fly ash - pot	1.5	1.7	carrot (peeled)	0.02	0.06	0.04	0.118	0.004	0.005	Furr et al. 1978
field-compost			onion				0.125	0.0550223	0.0687779	Cappon 1987
field-fly ash - pot	1.5	1.7	Onion (peeled)	0.02	0.21	0.1	0.125	0.02	0.025	Furr et al. 1978
field-fly ash-potted soil	0.3	1.2	potato	0.025	1.8	1.5	0.222	0.3	0.375	Furr et al. 1979
field-fly ash - pot	1.5	1.7	Potato (peeled)	0.02	0.03	0.02	0.222	0.004	0.005	Furr et al. (1978b)
field-compost			radish				0.222	0.0391143	0.0488929	Cappon 1987
field-compost			turnip				0.222	0.0112321	0.0140402	Cappon 1987

Average selenium uptake factor in root crops (fresh weight conc. in plant / wet weight conc. in soil) = 0.0689±0.114

H.13 References

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