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To: Interested Parties

From: Roger Brewer, Ph.D., Environmental Risk Assessor, HEER

Through: Barbara Brooks, Ph.D., Toxicologist, HEER

Subject: Update to Soil Action Levels for Inorganic Arsenic and Recommended Soil Management Practices (updates default, background arsenic soil action level presented in 2010 guidance to 24 mg/kg; arsenic exposure units in Section 3.0 table corrected to ug/day September 2012)

1.0 Introduction

This technical memorandum presents an update to the 2008 Hawaiʻi Department of Health (HDOH) action levels and corresponding guidance for inorganic arsenic in soil (HDOH 2008a, attached). Categories for management and evaluation of arsenic-contaminated soil have been revised and simplified. Soil action levels for arsenic presented in the 2008 technical memorandum have not been adjusted. This guidance serves as an addendum to the Hazard Evaluation and Emergency Response (HEER) office document *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (EHE guidance; HDOH 2008b).

Refer to the June 2010 dioxin technical memorandum for additional guidance on issues common to both dioxin- and arsenic-contaminated soil, including (HDOH 2010a):

- Site characterization;
- Disposal of contaminated soil;
- Engineering controls;
- Institutional controls;
- Management of Category C Soils at Commercial/Industrial Sites;
- Environmental Hazard Management Plans and management of Category C soils at commercial/industrial sites;
- Inclusion of soil above surrounding background in remediation of Category D soils; and

- Hazardous Waste Considerations.

The soil action levels presented herein are not promulgated regulatory standards or required cleanup levels. Alternative proposals may be presented in a site-specific risk assessment.

2.0 Arsenic Soil Management Categories

Updated categories for the evaluation and management of arsenic-contaminated soil are summarized below and in Table 1. These categories replace the scheme presented in the 2008 HDOH technical memorandum (HDOH 2008a):

<u>**Category A Soils (natural background):**</u> **Soils exhibit concentrations of total arsenic <24 mg/kg, and do not appear to have been impacted by local, agricultural or industrial releases of arsenic; not impacted.** The natural, background concentration of arsenic in soils in Hawai‘i is typically less than 24 mg/kg (<2mm soil fraction; upperbound background level, HDOH 2011). A summary of background concentrations of heavy metals in soil in Hawai’i is in preparation. In the interim, refer to documents published by the Air Force (USAF 2005) and Navy (USN 2006) environmental programs in Hawai‘i. A summary of background concentrations of metals in various soil types on the mainland US has been published by the University of California (UCR 1996) and U.S. Geological Survey (USGS 2001).

<u>**Category B Soils (minimally impacted):**</u> **Total arsenic >24 mg/kg but bioaccessible arsenic <23 mg/kg, indicating probable anthropogenic impacts but at levels within acceptable health risks for long-term exposure; Unrestricted Land Use.** Bioaccessible arsenic determined for 250 micron soil fraction. HEER expects Category B soils to be generally associated with agricultural fields where arsenic- based herbicides were used for weed control between the years 1915 to 1950. Arsenic levels between individual fields can vary with respect to the location of the field (e.g., high- versus low-rainfall area) as well as the weed control preferences of the sugar companies that managed the fields. Reported concentrations of bioaccessible arsenic are typically below 23 mg/kg in field areas, although exceptions have been identified in some areas. This action level can be easily exceeded in former pesticide storage and mixing areas. In general, bioaccessibility is higher in iron-poor, coralline sands in comparison to iron-rich volcanic soils.

Although not necessary from a health risk standpoint, owners of existing homes where pesticide-related, Category B soils are identified may want to consider measures to minimize exposure to arsenic in the soil as summarized in Table 1 and discussed in the HDOH fact sheet *Arsenic in Hawaiian Soils: Questions and Answers on Health Concerns* (HDOH 2010b; see also 2008c).

HDOH discourages the use of Category B soils with greater than 100 mg/kg *total* arsenic in the fines sol fraction (< 250µm) as fill material in offsite areas without further consultation, even if bioaccessible arsenic meets action levels for unrestricted use. This is intended to limit the movement of contaminated soil to otherwise un-impacted areas, as well as address a potential increase in bioaccessibility with the addition of phosphate fertilizers in lawns or gardens in new developments. Investigations carried out by HDOH in several heavily-impacted community garden soils on the Big Island (>400 mg/kg total arsenic in the fines soil fraction; HDOH 2007) suggested an increase in bioaccessible arsenic (15-20%) in comparison to equally-contaminated soils in the surrounding areas (1-10%). A limit of total arsenic to 100 mg/kg in fines is intended to approximate the target Category B limit of 23 mg/kg under a worst-case, 25% bioaccessibility for arsenic in iron-rich, volcanic soils.

Category C Soils (moderately impacted): Bioaccessible arsenic between 23 mg/kg and 95 mg/kg; Commercial/Industrial Land Use Only. Category C soils are exemplified by contamination at former pesticide storage and mixing areas and wood treatment facilities. Category C soils have also been identified in community gardens associated with former sugarcane plantations (with elevated arsenic also identified in the adjacent field areas), at the site of a former Canec manufacturing site (see HDOH 2010c), and in some industrial areas believed to have been historically treated with arsenic herbicides for weed control.

Category D Soils (heavily impacted): Bioaccessible arsenic greater than 95 mg/kg; Remedial Actions Required. Category D soils have been identified at a small number of former pesticide mixing areas (e.g., sugarcane operations), former plantation housing areas and wood treatment facilities. Concentrations of total arsenic in soil typically exceed several thousand milligrams per kilogram. These soils are often co-located with heavy dioxin contamination (associated with use of pentachlorophenol) and in some cases triazine pesticides. Pentachlorophenol and triazine pesticides successively replaced the use of arsenic-base herbicides in the 1930s and 1970s, respectively (see HDOH 2010a; refer also to Section 9 in the HEER office Technical Guidance Manual, HDOH 2009).

A site-specific, Environmental Hazard Management Plan (EHMP) must pre prepared for all sites where Category C and D soils are to be left in place for long-term management (HDOH 2008b, 2009). Information to be provided in the EHMP includes:

- To-scale maps that specify the location, thickness and depth of Category C and D soils;
- Summary of the specific environmental hazards potentially posed by the contaminated soil;
- Required institutional and engineering controls (e.g., restricted use, capping requirements, etc.);
- Fugitive dust and storm water runoff control measure;
- Measures for protection of workers involved in future construction or trenching projects that might disturb Category D soils.

Inappropriate reuse of Category C or D soils in offsite areas is of particular concern when excess soil is generated during construction or trenching projects. Clean fill should be used in utility corridors to minimize worker exposure and inadvertent reuse of removed soil in offsite areas. Refer to the HEER office *Environmental Hazard Evaluation* guidance (HDOH 2008b) and *Technical Guidance Manual* (HDOH 2009) for additional information. A copy of the EHMP should be retained by the property owner and lessees, as well submitted to HDOH for inclusion in the public record for the subject site.

3.0 Comparison of Soil Exposure to Dietary Exposure

The unrestricted (e.g., residential) soil action level of 23 mg/kg for bioaccessible, inorganic arsenic equates to a hypothetical, daily exposure dose for a 15kg child of approximately 4.0 micrograms (based on assumed soil ingestion rate, exposure duration and frequency, etc.; see HDOH 2008a). The commercial/industrial action level of 95 mg/kg equates to a daily exposure dose for a 70kg worker of 7.0 micrograms. Actual exposures to arsenic in soil for both children and adults are likely to be much lower due to the conservative nature of the exposure factors used in the calculations.

Exceeding the soil action level and the hypothetical exposure dose does not imply that an adverse health risk will occur, only that additional evaluation is warranted. This is because the Reference Dose (RfD) used to calculate the soil action level (i.e., 0.3 ug/kg-day; USEPA 2010a) incorporates an inherent uncertainty and margin of safety, due to the nature of toxicological risk assessment. As stated in IRIS summary for arsenic, “Risk managers should recognize the considerable flexibility afforded them in formulating regulatory decisions when uncertainty and lack of clear consensus (on toxicity factors) are taken into account.”

Arsenic is a naturally occurring element in the earth’s soil and water. As such it is naturally present in trace amounts in food. A comparison of exposure to inorganic arsenic in the diet to exposure from soil helps put the stated action levels into perspective, as shown in the table below (see Attachment 2 for detailed explanation):

	Exposure (ug/day)	
Receptor	*Soil	Dietary
Child (15 kg)	4.0	18
Adult (70 kg)	7.0	44

*Exposure to Category B (Child) and C (Adult Worker) soil.

Based on a typical Pacific-Asian diet that is rich heavy in rice and fish, dietary inorganic arsenic exposures are estimate to be as high as 18 ug/day for children (1.2 ug/kg-day for a 15 kg child) and 44 ug/day for adults (0.6 ug/kg-day for a 70 kg adult). Rice accounts for the majority of dietary, inorganic arsenic (see Attachment 2).

Dietary exposure to inorganic arsenic is therefore anticipated to far exceed exposure to arsenic in soil at the stated action levels. The majority of exposure to inorganic arsenic in the diet comes from rice (see Attachment 2), which naturally accumulates arsenic and other elements in the soil when grown under wet conditions. Regular consumption of rice has not been shown to pose a significant health risk due to the presence of arsenic or other metals. Fish contains a significant amount of relatively non-toxic, *organic* arsenic ("fish arsenic") but can also contribute to a small portion of total inorganic arsenic exposure.

4.0 Comparison to 2010 Draft USEPA Arsenic Toxicity Review

The USEPA published draft, proposed changes to the cancer slope factor for inorganic arsenic in February 2010 (USEPA 2010b). The draft USEPA document recommends an *increase* in current cancer slope factors for inorganic arsenic by more than an order of magnitude under some circumstances. In theory this could result in a *reduction* of cancer-based soil action levels by a similar magnitude. As stated in the draft USEPA document: "(This document) has not been formally disseminated by EPA. It does not represent and should not be construed to represent any Agency determination or policy."

The draft USEPA (2010b) cancer slope factors for arsenic are based on doses that are orders of magnitude higher than are typically associated with exposures to soils (e.g., 100s to 1,000s ug/day vs <5 ug/day for exposures to Category B soils. There is considerable debate among both regulators and private entities regarding the applicability of both current and proposed cancer slope factors to very low doses of inorganic arsenic typically associated with exposure to soil as well as rice and other foods (e.g., USSBA 2010, EPRI 2010). As described in the 2008 technical memorandum, HDOH places a higher level of confidence in the noncancer toxicity factors and feels that the use of these factors in the development of soil action levels is more technically supportable for regulatory decisions (HDOH 2008a).

The use of conservative exposure assumptions in conjunction with a comparison to anticipated dietary exposure to inorganic arsenic provide additional lines of evidence to support the adequacy of the soil action levels to help separate low-risk sites from high risk sites and prioritize HDOH resources. HDOH considers the current approach to develop soil action levels as outlined in the 2008 technical memorandum to be appropriate for use in Hawai‘i and does not anticipate the need to adjust them in the foreseeable future.

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Table 1. Summary of Inorganic Arsenic Soil Action Levels and associated soil management categories.

Soil Management Category	Action
Total Arsenic (< 2 mm size fraction)	
Category A Total Arsenic ≤24 mg/kg	**Background.** Within range of expected background conditions in non-agricultural and non-industrial areas (upperbound background noted, HDOH 2011). No further action required and no restrictions on land use.
Bioaccessible Arsenic (<250 μm size fraction)	
Category B Total Arsenic >24 mg/kg and Bioaccessible Arsenic ≤23 mg/kg	**Minimally Impacted-Unrestricted Land Use.** Exceeds expected background conditions but at levels anticipated for many agricultural fields where arsenic-based chemicals were used historically. Potential health risks considered to be within the range of acceptable health risks for long-term exposure. Include Category B soil in remedial actions for more heavily contaminated spill areas as practicable in order to reduce exposure (e.g., outer margins of pesticide mixing areas). Offsite reuse of soil for fill material not recommended for soil with >100 mg/kg total arsenic (see text). Use of soil for intermediate (e.g., temporarily inactive portions) or interim (e.g., daily or weekly) cover at a regulated landfill is acceptable, pending agreement by the landfill and barring hazardous waste restrictions. Although not strictly necessary from a health-risk standpoint, owners of existing homes where pesticide-related, Category B soils are identified may want to consider measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc) as described in the HDOH fact sheet *Arsenic in Hawaiian Soils: Questions and Answers on Health Concerns* (HDOH 2010c). For new developments on large, former field areas, notify future homeowners of elevated levels of arsenic on the property and recommend similar, precautionary measures (e.g., include in information provided to home buyers during property transactions, see also HDOH 2008b).
Category C (Bioaccessible Arsenic >23 but ≤95 mg/kg)	**Moderately Impacted-Commercial/Industrial Land Use Only.** Identified at several, former pesticide mixing areas and wood treatment facilities. May be co-located with pentachlorophenol, dioxin and triazine pesticide contamination at agricultural sites. Restriction to commercial/industrial land use is typically required in the absence of remediation or significant institutional and engineered controls and HDOH approval. Use of soil as soil as intermediate (e.g., temporarily inactive portions) or interim (e.g., daily or weekly) cover at a regulated landfill is acceptable, pending agreement by the landfill and barring hazardous waste restrictions. Preparation of a site-specific, *Environmental Hazard Management Plan* (EHMP) required if soil is left on site for long-term management (HDOH 2008b, 2009). Treatment to reduce bioavailability and/or removal of isolated spill areas is recommended when practicable in order to minimize future management and liability concerns. This includes controls to ensure no off-site dispersion (e.g., dust or surface runoff) or inadvertent excavation and reuse at

	properties with sensitive land uses.
Category D (Bioaccessible Arsenic >95 mg/kg)	**Heavily Impacted-Remedial Actions Required.** Identified at a small number of former pesticide storage and mixing areas (e.g., sugarcane operations), former plantation housing areas and wood treatment facilities. May be co-located with dioxin and triazine pesticide contamination. Remedial actions required under any land use scenario in order to reduce potential exposure. Potentially adverse health risks under both sensitive and commercial/industrial land use scenarios in the absence of significant institutional and/or engineered controls. Disposal of soil at a regulated landfill is acceptable, pending agreement by the landfill and barring hazardous waste restrictions. Preparation of site-specific EHMP required if left on site.

ATTACHMENT 1

2008 HDOH ARSENIC ACTION LEVEL GUIDANCE

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FROM: Roger Brewer
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THROUGH: Barbara Brooks
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DATE: June 13, 2008

SUBJECT: Tier 2 Action Levels for Arsenic (update to August 2006 memorandum)

This technical memorandum presents Tier 2 action levels and corresponding guidance for arsenic-contaminated soils. The guidance serves as an addendum to the Hazard Evaluation and Emergency Response (HEER) office document *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH 2008a). The guidance updates and takes precedence over guidance published in August 2006 (HDOH 2006). The update primarily addresses recommendations for the management of Category 2 soils in former agricultural fields. Similar guidance has been prepared for dioxin-contaminated soils (HDOH 2008b)

The guidance is especially intended for use during the redevelopment of former agricultural areas, although it is applicable to any site where releases of arsenic may have occurred. The action levels should be used to help determine the extent and magnitude of arsenic-contaminated soils and help guide the scope of remedial actions needed. The action levels are intended to serve as guidelines only, however, and do not represent strict, regulatory cleanup requirements. Alternative action levels may be proposed for any site in a site-specific, environmental risk assessment.

Overview

The action levels presented are based on concentrations of *bioaccessible* arsenic in soil. *Total* arsenic data are considered appropriate for comparison to anticipated background levels of arsenic in soil but not for use in human health risk assessment or for setting risk-based action levels. An action level of 4.2 mg/kg bioaccessible arsenic is recommended for residential sites. For commercial/industrial sites, an action level of 19 mg/kg bioaccessible arsenic is recommended. Remediation of sites to permit future, unrestricted, residential land use is encouraged when technically and economically feasible. “Residential” use includes both single-family homes and high-density developments, where open spaces essentially serve as residential “backyards.” Schools, parks, playgrounds, and other open public spaces that adult and child residents may visit on a regular basis should also be initially assessed under a residential use exposure scenario. Short- and long-term remedial actions in the latter areas may differ from actions recommended for high-density and single-family residential properties, however, due to greater control over digging and other activities that may expose contaminated soil.

Additional guidance and action levels are provided for sites where the preferred action levels noted above cannot be reasonably met and continued use or redevelopment of the site is still desired. Three categories of arsenic-contaminated soil are defined for both residential and commercial/industrial sites. Residential, Category 1 soils (R-1) are not considered to pose a significant risk to human health under any potential site conditions and can be reused onsite or offsite as desired. Commercial/Industrial, Category 1 soils (C-1) can be used as needed on commercial/industrial sites but should not be used as fill material offsite without prior consultation with HDOH.

Category 2 Residential (R-2) and Commercial/Industrial (C-2) soils are not considered to pose a significant risk to human health under the specified land use. As a best management practice, however, HDOH recommends the removal or capping of Category 2 soils associated with easily identifiable, localized spill areas when feasible (e.g., past pesticide mixing or storage). HDOH does not consider capping or removal of Category 2 soils in large, former field areas to be necessary or practicable.

Category 3 Residential (R-3) and Commercial/Industrial (C-3) soils are considered to pose an unacceptable risk to human health and should be removed from the site or isolated onsite under permanent structures or properly designed caps, as described below.

Remediation of residential and commercial/industrial properties to action levels for Category 2 soils is recommended to the extent technically and economically feasible, however, and should be discussed with the HEER office on a site-by-site basis. Reuse of Category 2 Commercial/Industrial soil for daily cover at a regulated landfill may be acceptable but should be discussed with the landfill operator as well as the HDOH Solid and Hazardous Waste Branch.

Background

Significantly elevated levels of arsenic have been identified in soils from former sugar cane fields and pesticide mixing areas in Hawaiʻi, as well as in and around former plantation camps. High levels of arsenic have also been identified in soil samples from at least one former golf course. The presence of the arsenic is believed to be related the use of sodium arsenite and other arsenic-based pesticides in and around the cane fields in the 1920s through 1940s. During this period, up to 200,000 acres of land in Hawaiʻi was being cultivated for sugar cane. The arsenic is generally restricted to the upper two feet of the soil column (approximate depth of plowing). Alternative action levels and approaches may be acceptable for contaminated soils situated greater than three feet below ground surface and should be discussed with HDOH on a site-by-site basis.

Current studies have focused on the Keaʻau area of the Big Island. Soils in the area have been described as stony, organic, iron-rich Andisols (Cutler et al., 2006). Concentrations of total arsenic in soils from undeveloped former sugar cane lands in this area have been reported to range from 100-400 mg/kg in the ≤2mm size fraction of the soil and >500 mg/kg in the <250µm size fraction (report pending). Concentrations greater than 1,000 mg/kg have been reported in one former plantation camp area. Background concentrations of arsenic in native soils range from 1.0 mg/kg up to 20 mg/kg. The presence of the arsenic initially posed concerns regarding potential groundwater impacts, uptake in homegrown produce and direct exposure of residents and workers to contaminated soil. Maximum-reported concentrations of bioaccessible arsenic in soil are far below levels that would cause immediate, acute health affects. Continued exposure to arsenic in heavily contaminated soils over many years or decades could pose long-term, chronic health concerns, however.

Arsenic has not been detected in municipal groundwater wells in the area. Testing of produce from gardens in the Kea‘au area by the Department of Health in 2005 also did not identify levels of arsenic above U.S. norms, even though total arsenic in the garden soils approached or exceeded 300 mg/kg in the ≤2mm size fraction. Uptake of the arsenic in edible produce or other plants therefore does not appear to be a significant environmental health concern. These observations suggest that the arsenic is tightly bound to the soil and not significantly mobile. This is further supported by petrologic and leaching studies as well as “bioaccessibility” tests conducted on the soils (Cutler et al., 2006). Despite being relatively immobile, however, elevated levels of arsenic in some areas could still pose a potential chronic health risk to residents and workers who come into regular contact with the soil. The action levels and soil categories discussed below are intended to address this concern.

The evaluation of soil for arsenic has traditionally focused on the *total* amount of arsenic present and comparison to action levels based on a target excess cancer risk of one-in-a-million or 10^{-6}. This has always presented a dilemma in human health risk assessments. Natural, background concentrations of arsenic in soils are typically much higher than risk-based action levels for total arsenic. For example, the residential soil action level for arsenic presented in the HDOH document *Screening For Environmental Concerns at Sites With Contaminated Soil and Groundwater* is 0.42 mg/kg (HDOH 2008a, Appendix 1, Table I-1), while background concentrations of arsenic in soil in Hawai‘i may range up to 20 mg/kg or higher. In addition, much of the arsenic in pesticide-contaminated soil appears to be tightly bound to soil particles and not *available* for uptake in the human body. This portion of the arsenic is essentially nontoxic. These two factors led to a need for further guidance, particularly with respect to the use of *bioaccessible* arsenic data in human health risk assessments and in the development of risk-based, soil action levels.

Bioavailable and Bioaccessible Arsenic

Risk to human health posed by exposure to a contaminant in soil is evaluated in terms of the average daily dose or *intake* of the contaminant for an exposed person (e.g., in milligrams or micrograms per day; USEPA 1989, 2004). Intake can occur through incidental ingestion of soils, inhalation of dust of vapors, and to a lesser extent (for most contaminants) absorption through the skin. Assumptions are made about the fraction of the contaminant that is available for *uptake* in a persons blood stream via the stomach and small intestine. This is referred to as the *bioavailability* of the contaminant (NEPI 2000). The most widely accepted method to determine the bioavailability of a contaminant in soil is through *in vivo* studies where the soil is incorporated into a lab test animal’s diet. In the case of arsenic, the amount that is excreted in the animal’s urine is assumed to represent the fraction that entered the animal’s blood stream and was available for uptake.

In vivo bioavailability tests are time consuming and expensive, however, and not practical for routine site evaluations. As an alternative, faster and more cost-effective laboratory tests have been developed to estimate arsenic bioavailability in soil. These methods, referred to as *in vitro* bioaccessibility tests, utilize an acidic solution intended to mimic a child’s digestive tract (typically a glycine-buffered hydrochloric acid solution at pH 1.5; Ruby 1999; Gron and Andersen, 2003). Soil with a known concentration and mass of arsenic is placed in the solution and allowed to equilibrate for one hour. An extract of the solution is then collected and analyzed for arsenic. The concentration of arsenic in the solution is used to calculate the total mass of arsenic that was stripped from the soil particles. The ratio of the arsenic mass that went into solution to the original mass of arsenic in the soil is referred to as the *bioaccessible* fraction of arsenic.

The results of *in vitro* bioaccessibility tests for arsenic compare favorably with *in vivo* bioavailability studies (Ruby 1999; Gron and Andersen, 2003). This is supported by studies of arsenic-contaminated soils from the Kea‘au area of the Big Island of Hawai‘i. Samples of the soil were tested for bioavailable arsenic in an *in vivo* monkey study carried out by the University of Florida in 2005 and simultaneously tested for bioaccessible arsenic by *in vitro* methods (report pending publication). The concentration of total arsenic in the samples was approximately 700 mg/kg. The study concluded that the bioavailability of arsenic in the soil ranged from 3.2% to 8.9%. This correlated well with an *in vitro* test carried out on the same soil that yielded an arsenic bioaccessibility of 6.5%. The bioaccessibility of arsenic in soils from the same site was estimated to range from 16% to 20% in a separate study, suggesting that the *in vitro* test method may err on the conservative side in comparison to the more standard *in vivo* method (Cutler et al., 2006). This has been observed in other studies of bioavailability versus bioaccessibility. Bioaccessibility tests on soils from other areas around Kea‘au yielded similar results and again indicated that 80% to >90% of the arsenic in the soil is so tightly bound to soil particles that it is essentially “nontoxic.”

Bioaccessible arsenic was observed to increase with increasing total arsenic concentration (Cutler et al., 2006). This is probably because much of the arsenic in heavily contaminated soils is fixed to low-energy binding sites on soil particles and comparatively easy to remove. Continued stripping of remaining arsenic from progressively higher-energy binding sites requires greater effort (i.e., the arsenic becomes progressively less bioaccessible). Data from the study also indicate that arsenic bioaccessibility (and therefore toxicity) may increase with increasing phosphorous concentration in soil related to the use of fertilizers in gardens. This is because phosphorus is able to out compete arsenic for high-energy binding sites on soil particles. The relationship has not been fully demonstrated, however, and is still under investigation.

Based on a review of published literature and studies conducted to date in Hawai‘i, HDOH considers arsenic bioaccessibility tests to be sufficiently conservative and an important tool in the assessment of arsenic-contaminated properties. Bioaccessible arsenic analyses should always be conducted on the <u><</u>250µm size fraction of the soil since this is the fraction that is most likely to be incidentally ingested. Most soils only contain a small percentage of particles 250µm in size or less. This typically requires the collection of very large samples (several kilograms) to obtain the mass needed for bioaccessibility tests. Appropriate sample handling, processing, and sub-sampling by the lab conducting bioaccessibility testing is essential. Guidance on suggested procedures and quality control for bioaccessibility lab tests will be forthcoming from HDOH. For more information on this subject contact John Peard of the HDOH HEER office (john.peard@doh.hawaii.gov).

Basis of Soil Action Levels

Arsenic action levels and correlative soil categories for residential and commercial/industrial properties are presented in Tables 1 and 2 and summarized in Figure 1. An action level of 20 mg/kg total arsenic in the <u><</u>2mm size soil fraction is recommended to screen out sites where naturally occurring (“background”) concentrations of arsenic are not significantly exceeded (HDOH 2008a). Background total arsenic may approach 50 mg/kg in some areas but this is considered rare. Analysis of soil samples for bioaccessible arsenic is recommended at sites where total arsenic exceeds anticipated background concentrations.

Action levels for bioaccessible arsenic are presented in Table 1 (residential land use) and Table 2 (commercial/industrial land use). The action levels are based on direct-exposure models used by USEPA to develop soil *Regional Screening Levels* (RSLs) (replace 2004 Preliminary Remediation Goals; USEPA 2008). The USEPA RSLs for arsenic for residential and commercial/industrial land use are 0.39 mg/kg and 1.6 mg/kg, respectively, based on a target excess cancer risk of $1x10^{-6}$ (one-in-a-million). Risk-based action levels for arsenic of 0.42 mg/kg and 1.9 mg/kg are presented in the HDOH document *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater*, based on a similar target risk but assuming a slightly lower, dermal absorption factor (HDOH 2008a). Both the USEPA RSLs and the HDOH Tier 1 action levels assume that 100% of the soil arsenic is bioavailable.

The USEPA RSLs and HDOH Tier 1 action levels for total arsenic are far below typical background concentrations of arsenic in soils from Hawai‘i, as well as most of the mainland US. To address this issue, action levels for Category 1 soils in Tables 1 and 2 are based on a target excess cancer risk of $1x10^{-5}$ (one-in-one-hundred-thousand) rather than $1x10^{-6}$. This generates residential and commercial/industrial action levels for bioaccessible arsenic of 4.2 mg/kg and 19 mg/kg, respectively. These action levels serve as useful starting points to help identify arsenic-contaminated sites that warrant further evaluation.

A second set of action levels is used to define soils that are most likely impacted above natural background levels but still may be acceptable for use in residential or commercial/industrial areas if adequate lawns and landscaping are maintained (Category 2 soils). An action level of 23 mg/kg bioaccessible arsenic was selected as an upper limit for soils in residential areas (Table 1). This reflects a noncancer Hazard Quotient of 1.0 and correlates to an excess cancer risk of approximately $5x10^{-5}$. Commercial/industrial action levels based on a similar excess cancer risk of $5x10^{-5}$ and a noncancer Hazard Quotient of 1.0 are 95 mg/kg and 310 mg/kg, respectively. Since the correlative action level for excess cancer risk is less than the action level for noncancer risk, the former (95 mg/kg) was chosen as an upper limit for soils in commercial/industrial areas (Table 2). These action levels are used to define the lower boundary of Category 3 soils.

At concentrations greater than 180 mg/kg, bioaccessible arsenic in soil begins to pose a potentially significant health risk to construction workers and utility workers (HDOH 2008a, refer to Table I-3 in Appendix 1, based on an excess cancer risk of $1x10^{-5}$). As discussed below, this is used as a “ceiling level” for soil that can be isolated under clean soil caps, buildings or paved areas.

The action levels for bioaccessible arsenic were used to group soils into three categories (see Tables 1 and 2). A discussion of potential remedial actions at each site that fall into these soil categories is provided in the following sections. The ultimate action taken at an individual site will be dependent on numerous site-specific factors, including current and planned land use, available options for onsite isolation or offsite disposal, and technical and economic constraints.

Soil Categories and Action Levels for use at Residential Sites

Category 1 Soils (R-1): Bioaccessible Arsenic ≤4.2 mg/kg, No Further Action

Long-term exposure to Category 1 (R-1) residential soils is not considered to pose a significant risk to residents. No further action is necessary at sites where the reported concentration of bioaccessible arsenic in soil is equal to or below 4.2 mg/kg.

Utility corridors should be backfilled with clean fill material (e.g., R-1 soils) or at a minimum R-2 soils in order to prevent excavation of contaminated soil and inappropriate reuse in other areas in the future. R-3 soils should not be placed in utility corridors.

Category 2 Soils (R-2): Bioaccessible Arsenic >4.2 mg/kg and ≤23 mg/kg, Consider Removal or Isolation of Localized Spill Areas

Long-term exposure to Category 2 (R-2) residential soils is not considered to pose a significant risk to residents. As a best management practice, however, HDOH recommends the removal or capping of Category 2 soils associated with easily identifiable, localized spill areas when feasible (e.g., past pesticide mixing or storage). HDOH does not consider capping or removal of Category 2 soils in large, former field areas to be necessary or practicable. These issues are discussed in more detail below.

At sites where R-2 soils are discovered in the vicinity of existing homes, residents should be encouraged to minimize exposure to the soil by taking the following precautions:

- Reduce areas of bare soil by planting and maintaining grass or other vegetative cover, or cover barren areas with gravel or pavement.
- Keep children from playing in bare dirt.
- Keep toys, pacifiers, and other items that go into childrens' mouths clean.
- Wash hands and face thoroughly after working or playing in the soil, especially before meals and snacks.
- Wash fruits and vegetables from home gardens before bringing them in the house. Wash again with a brush before eating or cooking to remove any remaining soil particles. Pare root and tuber vegetables before eating or cooking.
- Bring in clean sand for sandboxes and bring in clean soil for garden areas or raised beds.
- Avoid tracking soil into the house and keep the floors of the house clean. Remove work and play shoes before entering the house.

Testing of produce from gardens in the Kea'au area by the Department of Health in 2005 did not identify levels of arsenic above U.S. norms. Uptake of the arsenic in edible produce or other plants does not appear to be a significant environmental health concern in former sugar cane operation areas. Produce should be thoroughly cleaned before cooking or eating, however, in order to avoid accidental ingestion of small amounts of soil.

Category 3 Soils (R-3): Bioaccessible Arsenic >23 mg/kg, Removal or Isolation Recommended

Long-term exposure of residents to Category 3 (R-3) residential soils is considered to pose potentially significant health risks. As discussed above, maximum-reported concentrations of bioaccessible arsenic in soil from former agricultural areas are far below levels that would cause immediate, acute health affects. Continued exposure to arsenic in R-3 soils over many years or decades could pose long-term, chronic health concerns, however.

Offsite disposal of R-3 soils in a permitted landfill facility is recommended when technically and economically feasible. Reuse of some or all of the soil as daily cover at a landfill may also be possible. This should be discussed with the landfill in question as well as with the HDOH Solid and Hazardous Waste Branch. Offsite disposal of soil with bioaccessible arsenic in excess of 180 mg/kg is especially recommended (action level for construction/trench work exposure).

Soils that fall into this category but cannot be disposed offsite due to technical and/or cost constraints should be placed in *soil isolation areas*. Optimally, a soil isolation area would be created under public buildings, private roadways, parking lots and other facilities/structures that constitute a permanent physical barrier that residents are unlikely to disturb in the future. Isolation of R-3 soils under public roadways should be done in coordination with the local transportation authority. Isolation of R-3 soils under permanent structures is preferable to isolation in open areas, due to the increased potential for open areas to be inadvertently disturbed during future gardening, landscaping or subsurface utility work. Soil that cannot be placed under a permanent structure or disposed of offsite should be isolated in well-controlled common areas, rather than on individual residential lots. Contaminated soil should be consolidated in as few isolation areas as possible. Areas where R-3 soils are placed and capped for permanent onsite management must be clearly identified on surveyed, post-redevelopment map(s) of the property. These maps should be included a risk management plan that is provided to HDOH for inclusion in the public file for the site (see "Identification of Soil Isolation Areas" below). Utility corridors should be backfilled with clean fill material (e.g., R-1 soils) when initially installed or following maintenance work in order to prevent excavation and inappropriate reuse of contaminated soil in the future.

Depending on site-specific conditions, permanent covers or caps for soil isolation areas may be constructed of paving materials such as asphalt and concrete ("hard cap") or earthen fill material ("soil cap") that meets R-1 (preferred) or R-2 action levels. A soil cap thickness of 24 inches is recommended for areas where landscaping activities may involve digging deeper than one foot or where gardens may be planted in the future (based on USEPA guidance for lead-contaminated soils, USEPA 2003). A cap of twelve inches may be acceptable in high-density residential redevelopments where gardens will not be allowed and use of the area will be strictly controlled. A clearly identifiable, marker barrier that cannot be easily penetrated with shovels or other handheld digging tools (e.g., orange construction fencing or geotextile webbing) should be placed between the contaminated soil and the overlying clean fill material. A similar marker barrier should be placed below or above gravel, concrete or other hard material placed on top of contaminated soil in order to avoid confusion with former building foundations or road beds.

Permeable marker barriers may be necessary in areas of high rainfall in order to prevent ponding of water during wet seasons. Leaching tests should be carried out on R-3 soils in order to evaluate potential impacts to groundwater (see discussion below).

When R-3 soils are identified at existing homes, removal or permanent capping of the soils should be strongly considered. In the interim, residents should follow the measures outlined for residential R-2 soils to minimize their daily exposure. Children should avoid areas of bare soil and regular work in garden areas.

Soil Categories and Action Levels for use at Commercial/Industrial Sites

Category 1 Soils (C-1): Bioaccessible Arsenic >4.2 mg/kg and ≤19 mg/kg, No Further Action

Long-term exposure to Category 1 (C-1) soils is not considered to pose a significant health risk to workers at commercial or industrial sites. Remediation of soil that exceeds action levels for residential, R-1 (preferred) or R-2 action levels, however, will minimize restrictions on future land use and should be considered when feasible. Note that this may require a more detailed sampling strategy than is typically needed for commercial/industrial properties (e.g., decision units 5,000 ft^2 in size or less). Long-term institutional controls to restrict use of property to commercial/industrial purposes may be required if the site will not be investigated to the level of detail required for future, unrestricted land use to ensure that action levels for Category 2 Residential soils are not exceeded

Category 2 Soils (C-2): Bioaccessible Arsenic >19 mg/kg and ≤95 mg/kg, Consider Removal or Isolation

Long-term exposure to Category 2 (C-2) soils is not considered to pose a significant risk to workers provided that lawns and landscaping are maintained to minimize exposure and control fugitive dust or if the soils. Remediation of commercial/industrial properties to action levels approaching those for C-1 soils or lower is recommended when technically and economically feasible, however, and should be discussed with the HEER office on a site-by-site basis. When selecting remedial options, long-term effectiveness should be given increasing weight as concentrations of bioaccessible arsenic approach the upper boundary for C-2 soils.

For new developments, isolation of C-2 soils under buildings, private roadways and other areas with a permanent cap that workers are unlikely to disturb in the future is recommended when feasible. Isolation of C-2 soils under public roadways should be done in coordination with the local transportation authority. Offsite reuse of C-2 soil as fill material should be avoided. Reuse of some or all of the soil as daily cover in a regulated landfill may be feasible, however. This should be discussed with the landfill in question as well as with the HDOH Solid and Hazardous Waste Branch. Areas of the property where capped or uncapped C-2 soil is located must be clearly identified on surveyed, post-redevelopment map(s) of the property and included in a risk management plan that is documented in the HDOH public file for the site (see "Identification of Soil Isolation Areas" below). Care must be taken to ensure that soil from these areas is not excavated and inadvertently reused in offsite areas where residents could be exposed on a regular basis. Utility corridors should be backfilled with clean fill material (e.g., R-1 soils) when initially installed or following maintenance work in order to prevent excavation and inappropriate reuse of contaminated soil in the future.

At existing facilities, areas of bare C-2 soils should be minimized by maintaining grass or other vegetative cover or by covering bare areas with gravel or pavement. Workers should be encouraged to maintain clean work areas and thoroughly wash hands before breaks and meals.

Category 3 Soils (C-3): Bioaccessible Arsenic >95 mg/kg, Removal or Isolation Recommended

Long-term exposure to Category 3 (C-3) soils is considered to pose potentially significant health risks to workers at commercial or industrial sites. Offsite disposal of C-3 soils is recommended when technically and economically feasible. Offsite disposal of soil with bioaccessible arsenic in excess of 180 mg/kg is especially recommended (action level for construction/trench work exposure). Soil that cannot be removed from the site should be placed in designated isolation areas under public buildings, private roadways, parking lots and other facilities/structures that constitute a permanent physical barrier that residents are unlikely to disturb in the future. Contaminated soil should be consolidated in as few isolation areas as possible. Areas of the property where C-3 soil is located must be clearly identified on surveyed, post-redevelopment map(s) of the property and included in a risk management plan that is documented in the HDOH public file for the site (see "Identification of Soil Isolation Areas" below). Care must be taken to ensure that soil from these areas is not excavated and inadvertently reused in offsite areas where residents could be exposed on a regular basis. Utility corridors should be backfilled with clean fill material (e.g., R-1 soils) in order to prevent inadvertent excavation and reuse of contaminated soil in other areas in the future.

As discussed for residential sites, isolation of contaminated soil under buildings or other permanent structures is preferred over isolation in open areas. If placement of the soil in an open area is necessary, use of areas that are unlikely to be disturbed in the future is preferred. A minimum cap thickness of twelve inches is generally acceptable for commercial/industrial sites where use of the area will be strictly controlled (USEPA 2003). A clearly identifiable marker barrier should be placed between the contaminated soil and the overlying clean fill material (e.g., orange construction fencing or geotextile webbing). Fencing, geotextile fabric or similar, easily identifiable markers should likewise be placed above any gravel, concrete or other hard material placed on top of contaminated soil in order to avoid confusion with former building foundations or road beds.

Use of Total Arsenic Data

Based on data collected to date, it is possible that a significant portion of former sugar cane land situated in areas of high rainfall (e.g., >100 inches per year) will fall into the R-2 or C-2 soil categories as described above and summarized in Tables 1 and 2. Some of these areas have already been redeveloped for residential houses. Determination of bioaccessible arsenic levels on individual lots with existing homes may not be economically feasible for some residents (current analytical costs $500 to $1000). If site-specific, bioaccessible arsenic data is not affordable for a private homeowner, HDOH recommends that the soil be tested for total arsenic (generally less than $100). The resulting data should then be adjusted using a default *bioavailability* value to estimate bioavailable arsenic concentrations. Based on data collected to date in the Kea‘au area, a 10% bioavailability factor (BF) is recommended for total arsenic values at or below 250 mg/kg. Measured concentrations of total arsenic should be multiplied by 0.1 and the adjusted concentration compared to the action levels in Table 1 or Table 2. For total arsenic above 250 mg/kg, a more conservative bioavailability factor of 20% (0.2) is recommended.

For residential sites, this approach corresponds to an upper limit of 42 mg/kg total arsenic for R-1 soils and 230 mg/kg total arsenic for R-2 soils (10% BF used). For commercial/industrial sites, this corresponds to an upper limit of 190 mg/kg total arsenic for C-1 soils (10% BF used) and 475 mg/kg total arsenic for C-2 soils (20% BF used). Soils that potentially fall into Category 3 for residential or commercial/industrial sites should be tested for bioaccessible arsenic if at all possible. In the absence of bioaccessibility data, it is recommended that children avoid playing or working in gardens or other areas where total arsenic action levels indicate the potential presence of R-3 soils. The default bioaccessibility factors presented were developed based on data from the Kea‘au region and are subject to revision as more data becomes available.

The total arsenic action levels proposed above should not be used for general screening purposes at sites where a formal environmental investigation is being carried out. As previously discussed and as noted in the summary tables, bioaccessible arsenic data should be collected at all sites where total arsenic concentrations exceed an assumed background concentration of 20 mg/kg unless otherwise approved by HDOH.

Soil Sampling Methods

The use of multi-increment field soil sampling and lab sub-sampling techniques is recommended over the use of discrete or traditional composite sampling techniques. This sampling approach allows for the determination of a statistically representative concentration of arsenic within a specific area of investigation or “decision unit.”, such as an individual yard, a park, a garden or a well-defined spill area. Additional guidance on the use of multi-increment and decision unit investigation strategies will be provided in the 2008 update to the HEER office *Technical Guidance Manual.*

Other Potential Environmental Concerns

A discussion of environmental hazards associated with contaminated soil is provided in the HDOH document *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH 2008a). The arsenic action levels presented in this technical memorandum address human-health, direct-exposure hazards only. The action levels do not address potential leaching of arsenic from soil and subsequent impacts to underlying groundwater or potential toxicity to terrestrial flora and fauna. These issues should be evaluated on a site-specific basis as directed by HDOH. Arsenic is not considered to pose significant vapor intrusion or gross contamination hazards.

Based on data collected to date, leaching of arsenic from former sugar cane fields is not anticipated to pose a significant concern in Hawai‘i due to the apparent, relative immobility of the arsenic. Additional field data are needed to support this assumption, however, particularly for soils that exceed the upper action level for R-2 residential soils (i.e., >23 mg/kg bioaccessible arsenic). HDOH recommends that potential leaching of arsenic from soils that exceed 23 mg/kg bioaccessible arsenic be evaluated using the USEPA Synthetic Precipitation Leaching Procedure (SPLP) test or a comparable method. Refer to the HDOH technical memorandum *Use of Laboratory Batch Tests to Evaluate Potential Leaching of Contaminants from Soil* for additional guidance (HDOH 2007).

Assessment of additional pesticides and pesticide-related contaminants in agricultural areas should be carried out as needed based on the past use of the property. Refer to the 2008 update of the HEER office *Technical Guidance Manual* for additional information on target pesticides.

Environmental Hazard Evaluation Plans

Isolation areas where arsenic-contaminated soil is to be capped for permanent onsite management must be clearly identified on surveyed, post-redevelopment map(s) of the property. Areas of soil at commercial/industrial sites that exceed action levels for residential R-1, R-2 and R-3 soils should also be clearly surveyed and mapped. The maps identifying arsenic-impacted soils should be incorporated into an *Environmental Hazard Evaluation Plan* (EHMP, HDOH 2008a) that describes proper management, reuse and disposal of contaminated soil if disturbed during later redevelopment activities. A copy of the plan should be submitted to both HDOH and to the agency(s) that grants permits for construction, trenching, grading or any other activities that could involve future disturbance or excavation of the soil. The need to incorporate the risk management plan and specific land use restrictions in a formal covenant to the property deed should be discussed with HDOH on a site-by-site basis. Additional guidance on EHMPs will be provided in the 2008 update to the HEER office *Technical Guidance Manual*.

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Table 1. Soil categories and recommended actions for Residential Sites.

Total Arsenic (≤ 2 mm size fraction)	**Action**
≤20 mg/kg	Within range of natural background. No further action required and no restrictions on land use.
>20 mg/kg	Exceeds typical background. Re-evaluate local background data as available. Test soil for bioaccessible arsenic if background is potentially exceeded.
Bioaccessible Arsenic (≤250µm size fraction)	**Action**
R-1 Soils (≤4.2 mg/kg)	No further action required and no restrictions on land use.
R-2 Soils (>4.2 but ≤23 mg/kg)	Within USEPA range of acceptable health risk. Consider removal and offsite disposal of small, easily identifiable "hot spots" when possible in order to reduce potential exposure (not required for large, former field areas). Use of soil as daily cover at a regulated landfill may also be possible. For existing homes, consider measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.). For new developments on large, former field areas, notify future homeowners of elevated levels of arsenic on the property (e.g., include in information provided to potential buyers during property transactions).
R-3 Soils (>23 mg/kg)	For existing homes, removal or onsite isolation of exposed soil is strongly recommended. Consider a minimum one-foot cover of clean fill material (two feet in potential garden areas) if soil cannot be removed. An easily identifiable marker barrier should be placed between the contaminated soil and the overlying fill (e.g., orange construction fencing or geotextile/geonet material). In the interim, take measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.). Children should avoid areas of bare soil and regular work in gardens areas. For new residential developments, removal and offsite disposal of soil should be strongly considered. At a minimum, consider removal and offsite disposal of soil with concentrations of bioaccessible arsenic that approach or exceed 180 mg/kg (direct exposure action level for construction and trench workers). Use of soil as daily cover at a regulated landfill may be possible if concentrations of bioaccessible arsenic meet C-2 commercial/industrial soil criteria. If offsite disposal is not feasible but redevelopment of the property is still desired, consider use of soil as structural fill under public buildings, parking lots, private roads, or other paved and well-controlled structures. If capping in open areas is unavoidable, consider a one-foot minimum cap thickness with an easily definable marker barrier placed between the soil and the overlying clean fill (e.g., orange construction fencing or geotextile fabric). Capping of R-3 soils on newly developed, private lots is not recommended due to difficulties in ensuring long-term management of the soil. Backfill utility corridors with clean fill material (e.g., R-1 soils) to avoid excavation and inappropriate reuse of the soil in the future.

Table 1. Soil categories and recommended actions for Residential Sites (cont.).

R-3 Soils (cont.) (>23 mg/kg)	Require formal, long-term institutional controls to ensure appropriate management of soil in the future (e.g., Covenants, Conditions and Restrictions (CC&Rs), deed covenants, risk management plans, etc.). All areas of capped soil should be delineated on a surveyed map of the property to be subsequently included in the risk management plan.

The soil categories and arsenic action levels noted above are intended to be used as guidelines only and do not represent strict, regulatory cleanup requirements.

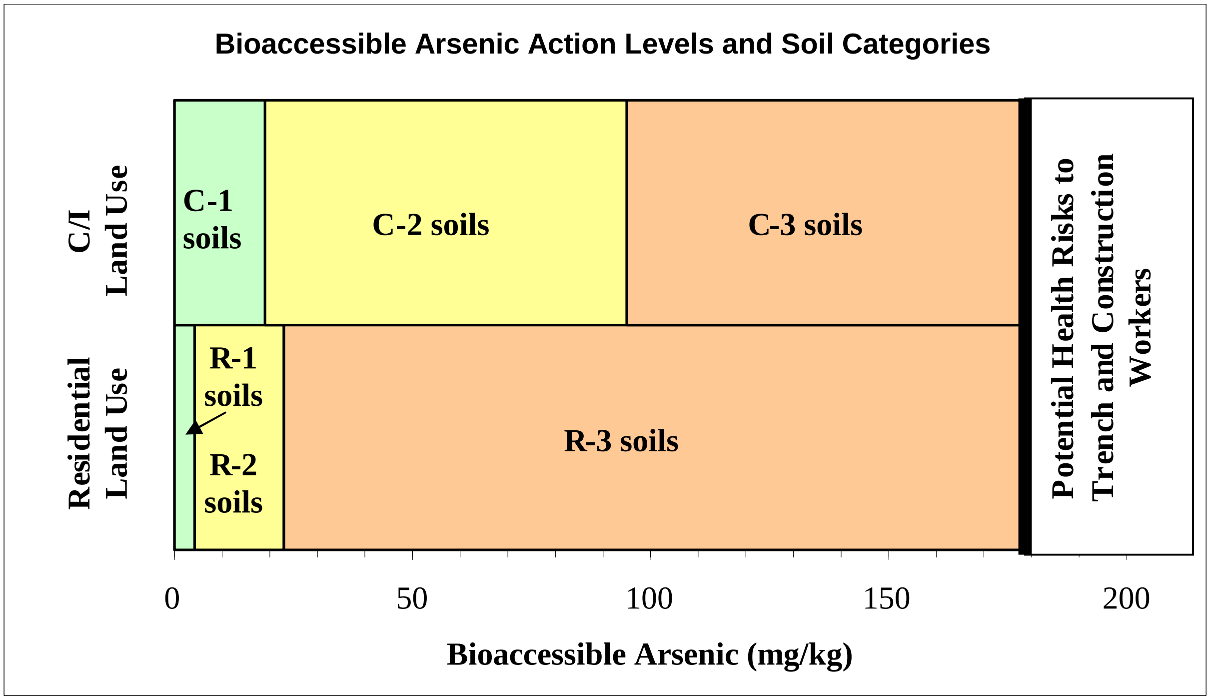
Table 2. Soil categories and recommended actions for Commercial/Industrial Sites.

Total Arsenic (≤ 2 mm size fraction)	**Action**
≤20 mg/kg	Within range of natural background. No further action required and no restrictions on land use.
>20 mg/kg	Exceeds typical background. Re-evaluate local background data as available. Test soil for bioaccessible arsenic if background is potentially exceeded.
Bioaccessible Arsenic (≤250μm size fraction)	**Action**
C-1 Soils (>4.2 mg/kg but ≤19 mg/kg)	No remedial action required. However, consider remediation of commercial/industrial properties to meet Residential R-1 (preferred) or R-2 action levels when feasible in order to minimize restrictions on future land use. Note that this may require a more detailed sampling strategy than typically needed for commercial/industrial properties (e.g., smaller decision units). Require formal, long-term institutional controls to restrict use of property to commercial/industrial purposes if the site will not be investigated to the level of detail required for future, unrestricted land use (i.e., inform potential buyers, deed covenants, risk management plans, etc.).
C-2 Soils (>19 but ≤95 mg/kg)	Remedial actions vary depending on site-specific factors, including current and planned use, available options for onsite isolation or offsite disposal, and technical and economical constraints (see text). Potential actions include: Consider removal and offsite disposal of small, easily identifiable "hot spots" when possible in order to reduce the average concentration of bioaccessible arsenic on the property. Use of C-2 soils as daily cover at a regulated landfill may also be possible. For sites that have already been developed, consider a minimum one-foot cover of clean fill material if the soil cannot be removed. If capping of soil is not feasible, consider measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, etc.). For new developments, consider isolation of soil under buildings, private roads or other permanent structures if technically and economically feasible. If isolation under permanent structures is not feasible, consider a minimum one-foot cover of clean fill material. Maintain landscaping and lawns in open areas where soil will not be capped. Backfill utility corridors with clean fill material (e.g., R-1 soils) to avoid excavation and inappropriate reuse of contaminated soil in the future. Require formal, long-term institutional controls to restrict use of site to commercial/industrial purposes only and ensure appropriate management of soil if exposed in the future (e.g., inform potential buyers, deed covenants, risk management plans, etc.). All areas of capped soil should be delineated on a surveyed map of the property to be subsequently included in the risk management plan.

Table 2. Soil categories and recommended actions for Commercial/Industrial Sites (cont.).

C-3 Soils (>95 mg/kg)	Removal of soil at existing commercial/industrial sites strongly recommended. At a minimum, consider removal and offsite disposal of soil with concentrations of bioaccessible arsenic that approach or exceed 180 mg/kg (direct exposure action level for construction and trench workers). If C-3 soils cannot be removed for technical or economic reasons, consider a minimum one-foot cover of clean fill material (two feet in potential deep landscaping areas) and placement of an easily identifiable marker barrier between the clean fill and the underlying soil (e.g., orange construction fencing or geotextile/geonet material). For new developments, removal and offsite disposal of soil should be strongly considered. At a minimum, consider removal and offsite disposal of soil with concentrations of bioaccessible arsenic that approach or exceed 180 mg/kg (direct exposure action level for construction and trench workers). If offsite disposal is not feasible but redevelopment of the property is still desired, consider use of soil as structural fill under public buildings, private roads, or other paved and well-controlled structures. If capping in open areas is unavoidable, consider a one-foot minimum cap thickness with an easily definable marker barrier placed between the soil and the overlying clean fill (e.g., orange construction fencing or geotextile/geonet material). Backfill utility corridors with clean fill material (e.g., R-1 soils) to avoid excavation and inappropriate reuse of contaminated soil in the future. Require formal, long-term institutional controls to ensure appropriate management of soil in the future (e.g., inform potential buyers, deed covenants, risk management plans, etc.). All areas of capped soil should be delineated on a surveyed map of the property to be subsequently included in the risk management plan.

The soil categories and arsenic action levels noted above are intended to be used as guidelines only and do not represent strict, regulatory cleanup requirements.



Residential Land Use Soil Categories		Commercial/Industrial Land Use Soil Categories	
R-1	≤4.2 mg/kg	C-1	≤19 mg/kg
R-2	>4.2 mg/kg to ≤23 mg/kg	C-2	>19 mg/kg to ≤95 mg/kg
R-3	>23 mg/kg	C-3	>95 mg/kg
>180 mg/kg: Potential risk to trench & construction workers			

Figure 1. Summary of bioaccessible arsenic action levels and correlative soil categories for residential and commercial/industrial (C/I) land-use scenarios.

ATTACHMENT 2

ESTIMATED DIETARY INTAKE OF TOTAL AND INORGANIC ARSENIC FOR PACIFIC-ASIAN DIETS

Dietary Exposure to Arsenic

A review of dietary exposure to total and inorganic arsenic was carried out by estimating daily consumption of the following food groups and typical concentrations of arsenic associated with each group:

- cereals & cereal products;
- starch roots and tubers;
- sugars and syrups;
- fats and oils;
- fish, meat and poultry;
- eggs;
- milk and products;
- dried beans, nuts and seeds;
- vegetables;
- fruits; and
- miscellaneous (beverages, condiments, etc.).

Consumption rates of each food group in a typical Filipino diet were compiled based on information published by the Philippine government and used as a surrogate for a typical Pacific-Asian diet (FNRI 2003, see Tables 1 and 2). Data are provided for children (ages 1-5) and the population as a whole (essentially adults). The data are provided for "As Purchased" food (e.g., raw vegetables, uncooked rice, etc.). A summary of the data is provided in Table 1.

Typical concentrations of inorganic and total arsenic in each food group were taken from a study of dietary exposure to arsenic in US children (Schoof et al. 1999, as presented in Yost et al. 2004; refer to Table 2). The data are based on prepared food (i.e., cooked meats and vegetables, including rice). While this is unlikely to introduce significant bias for meats and raw vegetables, the arsenic data for cooked rice cannot be directly compared to consumption data for uncooked rice. As an alternative, the estimated concentration of arsenic in rice is based on the average of 11 types of uncooked rice tested in a separate study (Williams et al 2005, as presented in Juhasz et al. 2006; refer to Table 1). Estimated concentrations of inorganic and total arsenic in seaweed was taken from a study carried out by the United Kingdom Food Standards Agency (UKFSA 2004).

The estimated daily, dietary intake of total arsenic is summarized in Figure 1. The estimated daily intake of inorganic arsenic is summarized in Figure 2. For children age one to five, the average exposure to dietary inorganic arsenic is estimated to be 18 ug/day, with 95% of the arsenic coming from rice. For the mean population (assumed representative of adults in general), the average exposure to dietary inorganic arsenic is estimated to be 44 ug/day, with a similar proportion of the arsenic coming from rice.

Dietary total arsenic is significantly higher, due primarily to the anticipated high consumption of fish and seaweed and the relatively high levels of organic arsenic in these foods. As noted in Table 1 and Figure 1, the average dietary total arsenic for children ages 1-5 is estimated to be 176 ug/day and for the mean population 339 ug/day. The consumption of fish provides approximately 75% of the total dietary arsenic, with the remainder of the total arsenic contributed by rice and seaweed (Nori seaweed assumed). Although organic arsenic is not considered to be significantly toxic, metabolism to DMA could complicate interpretation of the urine data collected for the target Filipino population.

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Table 1. Estimation of dietary exposure to total arsenic for a typical Filipino diet (surrogate for Pacific-Asian diet).

				Child (6mo-5yr)		Mean Population			
Food Group	[1]Child Consumption (g/d)	[1]Mean Consumption (g/d)	Total Arsenic (ug/kg)	Daily Dose (ug/d)	Percent Total Arsenic Contribution	Daily Dose (ug/d)	Percent Total Arsenic Contribution	[2]Reference	Comments
Cereals	**166**	**364**		**27.09**	**15.40%**	**65.4**	**19.28%**		
Rice & Products	122	303	208	25.4	14.42%	63	18.58%	Williams et al 2005	*in* Juhasz et al 2006
Corn and Products	17	31	38.6	0.66	0.37%	1.20	0.35%	Yost et al., 2004	
Other Cereals and Products	27	30	39.2	1.06	0.60%	1.18	0.35%	Yost et al., 2004	flour
Starch Roots and Tubers	**8**	**19**	**2.8**	**0.02**	**0.01%**	**0.05**	**0.02%**	Yost et al., 2004	potatoes
Sugars and Syrups	**15**	**24**	**23.8**	**0.36**	**0.20%**	**0.57**	**0.17%**	Yost et al., 2004	cane sugar
Fats and Oils	**6**	**18**	**1.8**	**0.01**	**0.01%**	**0.03**	**0.01%**	Yost et al., 2004	butter
Fish, Meat & Poultry	**95**	**185**		**135.61**	**77.08%**	**247.58**	**73.00%**	Yost et al., 2004	
Fish and Products	57	104	2356	134.29	76.34%	245.02	72.25%	Yost et al., 2004	Saltwater fish (Freshwater = 160 ug/kg)
Meat and Products	27	61	13.5	0.36	0.21%	0.82	0.24%	Yost et al., 2004	pork
Poultry and Products	11	20	86.40	0.95	0.54%	1.73	0.51%	Yost et al., 2004	chicken
Eggs	**8**	**13**	**0.98**	**0.01**	**0.00%**	**0.01**	**0.00%**	Yost et al., 2004	
Milk and Products	**179**	**49**		**0.39**	**0.22%**	**0.11**	**0.03%**	Yost et al., 2004	
Whole Milk	158	35	2.2	0.35	0.20%	0.08	0.02%	Yost et al., 2004	
Milk Products	21	14	2.2	0.05	0.03%	0.03	0.01%	Yost et al., 2004	
Dried Beans, Nuts & Seeds	**4**	**10**	**43.7**	**0.17**	**0.10%**	**0.44**	**0.13%**	Yost et al., 2004	
Vegetables	**23**	**111**		**12.08**	**6.87%**	**24.65**	**7.27%**	Yost et al., 2004	
Green Leafy & Yellow	10	31	6.1	0.06	0.03%	0.19	0.06%	Yost et al., 2004	spinach
Other Vegetables	3	80	5.8	0.02	0.01%	0.46	0.14%	Yost et al., 2004	average all other vegetables
Seaweed	0.5	1	24,000	12.00	6.82%	24.00	7.08%	UKSFA 2004	nori seaweed (1/2 MRL of 0.3 mg/kg)
Fruits	**31**	**54**		**0.16**	**0.09%**	**0.26**	**0.08%**	Yost et al., 2004	
Vitamin C-rich Fruits	4	12	2.5	0.01	0.01%	0.03	0.01%	Yost et al., 2004	oranges
Other Fruits	27	42	5.5	0.15	0.08%	0.23	0.07%	Yost et al., 2004	average all other fruits
Miscellaneous	**27**	**39**		**0.02**	**0.01%**	**0.03**	**0.01%**	Yost et al., 2004	
Beverages	26	26	0.8	0.02	0.01%	0.02	0.01%	Yost et al., 2004	tapwater used in cooking
Condiments & Others	1	13	0.8	0.001	0.0005%	0.01	0.003%	Yost et al., 2004	salt
Total Food Consumption:	562	886	**Total:**	**176**	**100.0%**	**339**	**100.0%**		

1. FNRI, 2003. Child = Average 6mo to 5 yrs. "As Purchased," cereals presumable dry weight.

2. See text for full reference.

Table 2. Estimation of dietary exposure to inorganic arsenic for a typical Filipino diet (surrogate for Pacific-Asian diet).

				Child (6mo-5yr)		Mean Population			
Food Group	**[1]Child Consumption (g/d)**	**[1]Mean Consumption (g/d)**	**Inorganic Arsenic (ug/kg)**	**Daily Dose (ug/d)**	**Percent Inorganic Arsenic Contribution**	**Daily Dose (ug/d)**	**Percent Inorganic Arsenic Contribution**	**Reference**	**Comments**
Cereals	**166**	**364**		**17.33**	**96.6%**	**42.6**	**97.5%**		
Rice & Products	122	303	139.0	17.0	94.6%	42	96.4%	Williams et al 2005	*in* Juhasz et al 2006
Corn and Products	17	31	4.4	0.07	0%	0.14	0%	Yost et al., 2004	
Other Cereals and Products	27	30	10.9	0.29	2%	0.33	1%	Yost et al., 2004	flour
Starch Roots and Tubers	**8**	**19**	**0.8**	**0.01**	**0.0%**	**0.02**	**0.0%**	Yost et al., 2004	potatoes
Sugars and Syrups	**15**	**24**	**4.4**	**0.07**	**0%**	**0.11**	**0.2%**	Yost et al., 2004	cane sugar
Fats and Oils	**6**	**18**	**1.2**	**0.01**	**0.0%**	**0.02**	**0.0%**	Yost et al., 2004	butter
Fish, Meat & Poultry	**95**	**185**		**0.08**	**0.5%**	**0.16**	**0.4%**	Yost et al., 2004	
Fish and Products	57	104	1.0	0.06	0.3%	0.10	0.2%	Yost et al., 2004	Saltwater fish (Freshwater = 160 ug/kg)
Meat and Products	27	61	0.67	0.02	0.1%	0.04	0.1%	Yost et al., 2004	pork
Poultry and Products	11	20	0.89	0.01	0.1%	0.02	0.0%	Yost et al., 2004	chicken
Eggs	**8**	**13**	**0.98**	**0.01**	**0.0%**	**0.01**	**0.0%**	Yost et al., 2004	
Milk and Products	**179**	**49**		**0.18**	**1.0%**	**0.05**	0.1%	Yost et al., 2004	
Whole Milk	158	35	1.0	0.16	0.9%	0.04	0.1%	Yost et al., 2004	
Milk Products	21	14	1.0	0.02	0.1%	0.01	0.0%	Yost et al., 2004	
Dried Beans, Nuts & Seeds	**4**	**10**	**4.7**	**0.02**	**0.1%**	**0.05**	**0.1%**	Yost et al., 2004	
Vegetables	**23**	**111**		**0.14**	**0.8%**	**0.54**	**1.2%**	Yost et al., 2004	
Green Leafy & Yellow	10	31	6.1	0.06	0.3%	0.19	0.4%	Yost et al., 2004	spinach
Other Vegetables	3	80	2.6	0.01	0.0%	0.21	0.5%	Yost et al., 2004	average all other vegetables
Seaweed	0.5	1	150	0.08	0.4%	0.15	0.3%	UKSFA 2004	nori seaweed (1/2 MRL of 0.3 mg/kg)
Fruits	**31**	**54**		**0.07**	**0.4%**	**0.12**	**0.3%**	Yost et al., 2004	
Vitamin C-rich Fruits	4	12	2.5	0.01	0.1%	0.03	0.1%	Yost et al., 2004	oranges
Other Fruits	27	42	2.1	0.06	0.3%	0.09	0.2%	Yost et al., 2004	average all other fruits
Miscellaneous	**27**	**39**		**0.02**	**0.1%**	**0.03**	**0.1%**	Yost et al., 2004	
Beverages	26	26	0.8	0.02	0.1%	0.02	0.0%	Yost et al., 2004	tapwater used in cooking
Condiments & Others	1	13	0.8	0.001	0.00%	0.01	0.02%	Yost et al., 2004	salt
Total Food Consumption:	562	886	**Total DD:**	**18**		**44**			

1. FNRI, 2003. Child = Average 6mo to 5 yrs. "As Purchased," cereals presumable dry weight.
2. See text for full reference.

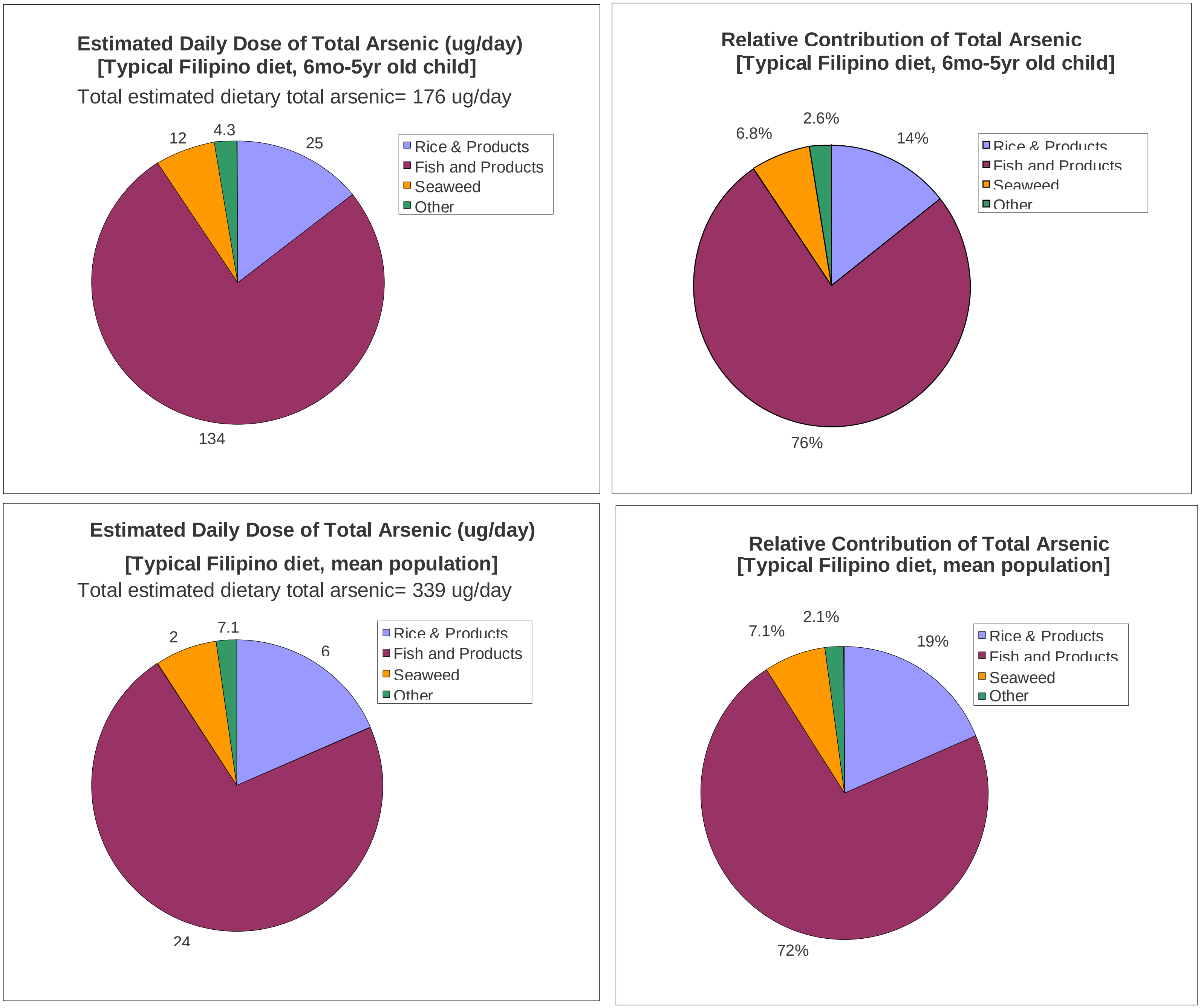

Figure 1. Estimated total arsenic intake based on a typical Filipino diet (surrogate for Pacific-Asian diet, refer to Table 1).

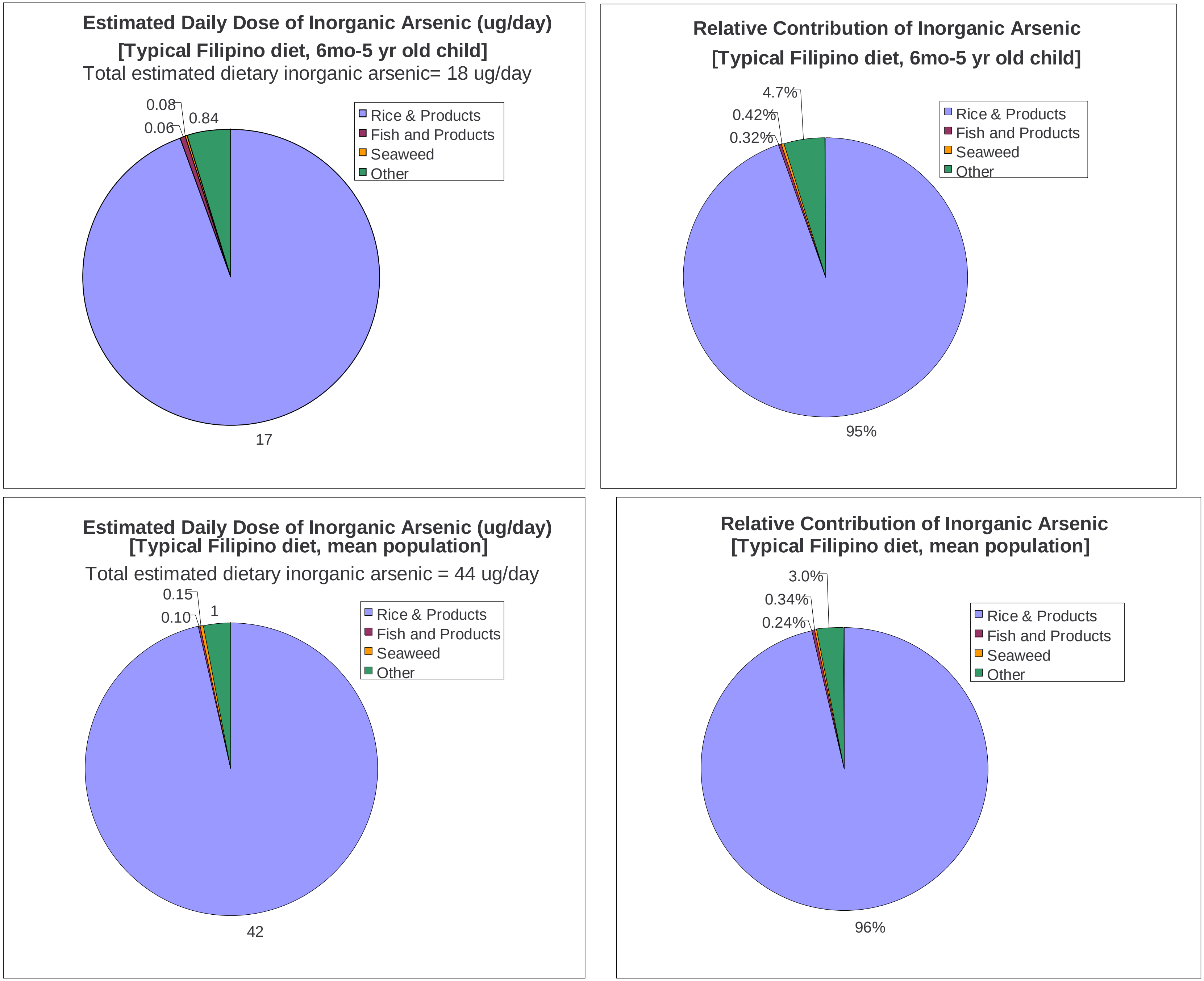

Figure 2. Estimated inorganic arsenic intake based on a typical Filipino diet (surrogate for Pacific-Asian diet, refer to Table 2).