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PUBLIC HEALTH ASSESSMENT

ANDERSEN AIR FORCE BASE
YIGO, GUAM

EVALUATION OF ENVIRONMENTAL CONTAMINATION AND EXPOSURE PATHWAYS

Introduction

What is meant by exposure?

ATSDR's PHAs are exposure, or contact, driven. Given sufficient exposure levels, chemical contaminants disposed of or released into the environment have the potential to cause adverse health effects. However, *a release does not always result in exposure*. People can only be exposed to a contaminant if they come in contact with that contaminant. Thus, people can be exposed if they breathe, eat, or drink a substance containing the contaminant or if their skin touches a substance containing the contaminant.

How does ATSDR determine which exposure situations to evaluate?

ATSDR scientists evaluate site conditions to determine if people could have been, are being, or could be exposed to site-related contaminants: scenarios are evaluated for past, current, and future exposure. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, waste, or biota) has occurred, is occurring, or will occur through ingestion, dermal (skin) contact, or inhalation.

ATSDR then identifies an exposure pathway as completed or potential, or not completed. If a pathway is not complete, there can be no exposure and ATSDR eliminates that pathway from further evaluation. A completed exposure pathway exists in the past, present, or future if all elements of human exposure link the contaminant source to a receptor population. A potential pathway is one that ATSDR cannot rule out, as conditions may change that could result in a future completed pathway.

If exposure was, is, or could become possible, ATSDR scientists consider whether contamination is present at levels that might affect public health. ATSDR scientists select contaminants for further evaluation by comparing them against health-based comparison values (CVs). CVs are developed by from scientific literature available on exposure and health effects. These CVs are derived for each of the

different media. CVs reflect an estimated contaminant concentration that is *not likely* to cause adverse health effects for a given chemical, assuming a standard daily contact rate (e.g., amount of water or soil consumed or amount of air breathed) and body weight.

CVs are not thresholds for adverse health effects. CVs establish contaminant concentrations many times lower than levels at which no effects were observed in experimental animals or human epidemiologic studies. If contaminant concentrations are above CVs, ATSDR further analyzes exposure variables (for example, duration and frequency), the toxicology of the contaminant, other epidemiologic studies, and the weight of evidence to assess the possibility of health effects.

Some of the CVs used by ATSDR scientists include ATSDR's environmental media evaluation guides (EMEG), reference dose media guides (RMEG), and cancer risk evaluation guides (CREG), and also EPA's maximum contaminant levels (MCL). MCLs are enforceable drinking water regulations developed to protect public health. CREGs, EMEGs, and RMEGs are non-enforceable, health-based CVs developed by ATSDR for screening environmental contamination for further evaluation.

More information about the ATSDR evaluation process can be found in ATSDR's Public Health Assessment Guidance Manual at http://www.atsdr.cdc.gov/HAC/HAGM/ or by contacting ATSDR at 1-888-42ATSDR (1-888-422-8737).

If someone is exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects that occur in an individual from contact with a contaminant depend on the exposure concentration (how much), the frequency and/or duration of exposure (how long), the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (the combination of contaminants involved). Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed individual influence how the individual absorbs, distributes, metabolizes, and excretes the contaminant. Together, these factors and characteristics determine the health effects that may occur as a result of exposure to a contaminant in the environment.

In a situation involving environmental contamination, there is usually considerable uncertainty about the true level of exposure to that contamination. To account for the uncertainty and to be protective of public health, ATSDR scientists typically use high-end, worst-case exposure level estimates as the basis for determining whether adverse health effects are possible. These estimated exposure levels usually are much higher than the levels to which people are really exposed. If the exposure levels indicate that adverse health effects are possible, ATSDR performs a more detailed review of exposure, taking into account scientific information from the toxicologic and epidemiologic literature about the health effects from exposure to hazardous substances. Figure 3 provides an overview of ATSDR's exposure evaluation process.

What exposure situations were evaluated for Andersen AFB?

ATSDR identified five exposure situations at Andersen AFB for further evaluation: consumption of contaminated groundwater, consumption of local biota, contact with contaminated surface soil, exposure to radon in on-base buildings, and encounters with physical hazards. Our evaluation is summarized in

Appendix A, Table 1, and discussed in greater detail in the following discussion. To acquaint the reader with terminology and methods used in this PHA, Appendix B provides a glossary of environmental and health terms presented in the discussion and Appendix C describes the methods ATSDR used to estimate exposure.

It should be noted that ATSDR analyzed all 39 of Andersen AFB's IRP sites to determine if they are associated with past, current, or future public health hazards. Appendix A provides a description and a summary of our evaluation for each site. Our review indicated that most sites at Andersen AFB are not associated with any known public health hazards because: (1) no site-related contaminants are present, (2) contaminant concentrations detected are too low to pose a health hazard, or (3) past and current exposure to the general public has been prevented.

ATSDR examined potential air contamination and found that the ambient air of Guam remains relatively clean at all times due to prevailing winds that carry clean air from the ocean across the island (USAF 1998a).

Evaluation of Groundwater Exposure Pathway

Conclusions

After detailed review of the available data, ATSDR concludes that no apparent public health hazards are associated with the use (past, current, and future) of groundwater from municipal, military, or private production wells.

Discussion

Andersen AFB's Hydrogeology

Andersen AFB property overlies five of the six groundwater subbasins of the Northern Guam Lens Aquifer: Yigo, Andersen, Agafo Gumas, Finegayan, and Mangilao (see Figure 2).[(2)] Three subbasins, the Andersen, Agafo Gumas, and Finegayan, underlie the main base property. Part of the Yigo subbasin lies under the MARBO Annex. The Yigo Subbasin groundwater flows west-southwest, toward Tumon Bay; Andersen Subbasin flows east and northeast; Agafo Gumas Subbasin flow patterns are unpredictable; and Finegayan Subbasin flows northward (EA Engineering 1998). The subbasins are presumably separated from one another by buried volcanic formations that create subsurface watershed divides (SAIC 1991). Past IRP investigations and documents have assumed that this volcanic material prevents groundwater contaminants from passing between the subbasins, but studies to date do not confirm these hydrogeological boundaries (ICF 1994).

Groundwater Use

The Northern Guam Lens Aquifer serves as a source of potable water for Andersen AFB and residents of Guam. Currently, the aquifer supplies approximately 70% of the drinking water to Guam and surface water provides the remaining 30% (SAIC 1991).[(3)] All of Andersen AFB water comes from the Yigo Subbasin, while about 47% of Guam's water comes from the Yigo, Andersen, Agafo Gumas, and Finegayan Subbasins (USAF 1998b).

Andersen AFB supports nine production water wells that have the ability to draw groundwater from the Yigo Subbasin of the Northern Guam Lens Aquifer for military potable water/drinking water uses. The production wells are: military well (MW) 1, 2, 3, 5, 6, 7, 8, and 9 in the MARBO Annex and one well (the Tumon-Maui well) located at Tumon Bay (Andersen AFB 1999a). Since the mid-1990s, both MW-2 and the Tumon-Maui wells have been off line because of environmental contamination concerns. The operating production wells provide approximately 2.5 to 3.2 million gallons of water a day for the base. When it was operating, the Tumon-Maui well supplied the bulk of the water, providing over 30% of the base's water capacity (Earth Tech 1998). Through the GEPA's groundwater protection program, the Air Force maintains a 1,000-foot protective zone around the water supply wells. The Andersen Subbasin reportedly supplied groundwater to the base during the 1940s and 1950s, but those wells are no longer used for drinking water due to poor water production and/or high salinity (SAIC 1991).

Since the 1950s, Andersen AFB has operated a water distribution system. Water drawn from each production well enters the base's looped distribution system, where it is blended with water from other wells before being distributed to Booster Stations 2 and 3 for chlorination (SAIC 1991; Andersen AFB 1999a). Groundwater from MW-1 and MW-3 are generally treated at Booster Station 2 (as were MW-2 and the Tumon-Maui when they were on line). Occasionally, all water is treated at Booster Station 3. (Two air stripping towers have also been added to Booster Station 2 to remove volatile organic compounds, or VOCs, from water originating from MW-2 and the Tumon-Maui well.) The water is then stored at one of three larger or several smaller water storage tanks, including Tank No. 2, located at Booster Station 2, Tank No. 4, located at Booster Station 3, and the Santa Rosa Reservoir. The Santa Rosa Reservoir (the largest tank, with a capacity of 2 million gallons) provides pressure for the distribution system. Andersen AFB's water supply distribution lines are prone to corrosion, and many of the valves are old and rusted (Earth Tech 1998). Since 1993, the Air Force has been systematically replacing the corroded distribution lines within the family housing area. They will continue to upgrade the system through 2001 (Andersen AFB 1999a).

The Northern Guam Lens Aquifer also yields approximately 22 million gallons of water per day via 85 production wells owned and operated by the Public Utility Agency of Guam (GWA). Twenty of these GWA production wells are located near Andersen AFB property and have been evaluated as if they are potentially at risk for contamination associated with Andersen AFB.

There are seven other active production wells, not owned by the Air Force or GWA, that are on or adjacent to Andersen AFB property. Two of these wells water a golf course near the Northwest Field OU (Andersen Subbasin water); two are hand-dug wells on private property north of the Northwest Field (Agafo Gumas Subbasin water); two (one of which is blocked) are United States Navy wells in the Harmon Annex OU (Finegayan and Yigo Subbasin water); and one is a United States Geological Survey well in the Main Base OU (Andersen Subbasin water).

What are VOCs?

Volatile organic compounds (VOCs) are a group of organic chemicals having similar physical properties. VOCs easily evaporate when exposed to air. Chemicals in this group include trichloroethylene (TCE) and tetrachloroethylene (PCE). These chemicals are cleaning solvents commonly used for degreasing, dry cleaning, paint thinners, and fuel additives.

High levels of TCE and PCE have been found in the groundwater at Andersen AFB and much lower levels have been found in base water supply wells. VOCs can get into your body if you drink contaminated water. Depending on the amount that enters the body and the exposure duration, VOCs can cause health effects.

The two private production wells are the only wells used for drinking water (EA Engineering 1998). Each private well serves one extended family and neither well is used on a full-time basis.

Groundwater and Drinking Water Quality

On-Base Groundwater Monitoring Wells

Andersen AFB began monitoring groundwater in 1987 to characterize the distribution and concentrations of contaminants in groundwater associated with the base and its annexes: the Main Base, the Northwest Field, the MARBO Annex, and the Harmon Annex. (The Air Force has stopped monitoring wells at the Harmon Annex because of lack of evidence of groundwater contamination [Dames & Moore 2000]). They collected samples routinely from a series of *groundwater monitoring wells* and analyzed the samples for VOCs, metals, and other site-related compounds. Samples from groundwater monitoring wells indicate the extent of the contamination and whether any contaminants are moving toward drinking water supplies. Figures 4a and 4b illustrate site locations, and Figures 5a and 5b show suspected groundwater plumes.

VOCs and metals have been detected in the groundwater monitoring wells that draw from the Yigo, Andersen, and Finegayan Subbasins. Groundwater contaminant concentrations that exceeded ATSDR's CVs and EPA's maximum contaminant levels (MCLs) are TCE, PCE, carbon tetrachloride, and lead. High levels of TCE have appeared in a cluster of monitoring wells on the northwest side of the MARBO Annex (Yigo Subbasin), near the Waste Transfer Stations. The highest levels of TCE (up to 466 parts per billion, or ppb, in October 1999) have been consistently found in the deep monitoring well IRP 31, located at IRP 37/War Dog Borrow Pit directly south of the CPA Power Plant (Dames & Moore 2000). Additionally, elevated levels of PCE have been measured in monitoring wells IRP 14 (up to 26 ppb in 1989) and IRP 29 (14 ppb in 1997) adjacent to the MARBO Annex laundry. The dry cleaning facility at the laundry may, in the past, have discharged PCE to the base sanitary sewer via floor drains (Montgomery Watson 1998). PCE levels detected at well IRP 14 have steadily declined over the years, but, as of 1999, were still above EPA's MCL of 5 ppb (Dames & Moore 2000).[(4)]

Investigations revealed that, in the groundwater beneath the Northwest Field OU and the Harmon Annex OU, VOCs and metals were not present or existed only at low levels. Contamination was found at the Main Base monitoring wells IRP 3 and USGS-150: at those wells, VOCs (TCE, PCE, or carbon tetrachloride) and metals (lead, chromium, and cadmium) exceeded EPA's MCL (EA Engineering 1998). No base drinking water wells, however, exist near these affected monitoring wells.

On-Base Production Wells (Drinking Water Supply Wells)

The Air Force collects samples from *on-base production wells*. These wells supply Andersen AFB with its source of drinking water. The Air Force routinely monitors these wells under requirements set forth by EPA's the Safe Drinking Water Act to ensure safe drinking water for base workers and residents. Currently, drinking water quality data are collected on a biannual basis. Production wells in the MARBO Annex and in the Tumon-Maui have also been extensively monitored since 1978 for select compounds, including TCE, methylene chloride, pesticides (e.g., endrin, lindane methoxychlor, toxaphene, 2,4,5,-T, 2,4-D), nitrates, and certain metals (SAIC 1991).

Through their routine monitoring, the Air Force discovered TCE in samples collected from base water supply wells MW-1 and MW-2 at levels above EPA's MCL (5 ppb). Both these wells are west of, and slightly downgradient from, monitoring well IRP 31, where monitoring found elevated levels of TCE. The TCE concentrations in MW-1 and MW-2 have fluctuated over time. For example, TCE in MW-1 increased from 2 ppb in 1978 to about 8.5 ppb in 1988, and then decreased to about 0.8 ppb in 1999. Even higher levels of TCE have been detected in MW-2, where concentrations fluctuated from a high of about 39 ppb in 1978 to less than 5 ppb in 1985, increased to about 24 ppb in 1986, and then decreased to 2.6 ppb in 1999 (Montgomery Watson 1998; Dames & Moore 2000). The Air Force closed MW-2 in October 1995 (USAF 2001).

Monitoring also found elevated levels of PCE in the Tumon-Maui well located in lower Tumon Village on Route 14. The Air Force shut down the well in 1995 after the concentrations of PCE collected that year averaged 10 ppb--levels that exceed ATSDR's CV and EPA's MCL of 5 ppb (Andersen AFB 1997). Booster Station No. 2, which received water from the well, contained an average of 6 ppb PCE.

Certain on-site production wells tested during the IRP investigations had elevated concentrations of metals (SAIC 1991). Antimony was detected above ATSDR's CV in two military production wells

(MW-2 at 0.4 parts per million, or ppm; MW-9 at 0.5 ppm). Elevated concentrations of beryllium occurred in MW-9, with a maximum detected concentration of 66 ppm. Although all these wells lie in or near the MARBO Annex OU and draw water from the Yigo Subbasin, the elevated metal concentrations do not appear to result from activities associated with Andersen AFB operations (EA Engineering 1998).

To address the contamination in the base production wells, the Air Force installed two air stripping towers at Booster Station 2. The air stripping towers were designed to remove up to 99% of the PCE and TCE before the drinking water reached the base taps. The towers have treated incoming water from MW-2 for TCE and water from the Tumon-Maui well for PCE. MW-2 and the Tumon-Maui well, however, closed again in 1999 due to calcification of pumps associated with air stripping towers. (The base planned to add sodium metaphosphate to the water supply to remedy the calcification and to resume operation.) Today, both MW-2 and the Tumon-Maui well are closed indefinitely. The base has no plans to reuse the Tumon-Maui well in the future (Earth Tech 1998; USAF 2001).

Except for the MW-1 and MW-2 wells (in the MARBO Annex) and the Tumon-Maui well, no other drinking water wells have been or are likely impacted by VOC contamination because either: (1) contamination is not present upgradient of the well or (2) contamination though present upgradient of the active well, is at relatively low levels.

Off-Base Drinking Water Supply Wells

ATSDR identified only one OU--the MARBO Annex OU, overlying the Yigo Subbasin--that has the potential to impact municipal drinking water wells. Specifically, in the eastern Yigo Subbasin, a TCE plume appears to originate in the vicinity of two waste piles, IRP 23/WP-5 and IRP 20/WP-7 (SAIC 1991). TCE contamination, however, has not been detected in active, downgradient municipal wells. Another Yigo Subbasin plume, containing PCE at a maximum detected concentration of 26 ppb, appear to originate from unknown sources near the former MARBO Laundry Facility and WP-6 in the MARBO Annex (SAIC 1991). No PCE contamination has ever been detected in the water of the northern city of Dededo.

The two private wells north of the Northwest Field are still in used as a source of drinking water Groundwater monitoring results for the Northwest Field revealed that VOCs and metals were either not present or existed only at low levels, and that contamination did not appear to be moving in a plume north toward the private wells (EA Engineering 1998).

Evaluation of Public Health Hazards

Past Exposure

TCE and PCE are the only contaminants that were detected in active on-base drinking water wells above ATSDR CVs and EPA's MCL. Historically, TCE was consistently detected at the wellhead in two (of the nine) drinking water wells located in the MARBO Annex. These wells supplied Andersen AFB with potable water (SAIC 1991; Montgomery Watson 1998). Elevated PCE levels were detected in the Tumon-Maui well (Earth Tech 1998; Montgomery Watson 1998). The maximum detected TCE concentrations at MW-1 and MW-2 were 8.5 and 39 ppb, respectively (SAIC 1991; Montgomery Watson 1998). The maximum concentration of PCE at the Tumon-Maui well was 10 ppb. PCE

concentrations in the distribution system were less than at the wellhead, but they still slightly exceeded ATSDR's CV and EPA's MCL of 5 ppb (Williams 1993; Andersen AFB 1997).

ATSDR did not identify any completed groundwater exposure pathways in the Main Base OU, Northwest Field OU, or Harmon Annex OU, because no drinking water wells are located in these areas. Exposure, if any, could only come from drinking water supplied by wells in the MARBO Annex or the Tumon-Maui well.

To evaluate whether harmful exposures occurred, ATSDR conservatively estimated past exposure doses to TCE- and PCE-contaminated groundwater (see Appendix C) and found that its dose estimates were below levels of public health concern, even when assuming that an individual drank all his/her water from the affected wells for over a 30 year period. Therefore, ATSDR concludes that *no apparent public health hazards* are associated with the past ingestion of groundwater from Andersen drinking supply wells. The Air Force further minimized past public exposures to contaminated groundwater by installing air strippers to treat water from MW-2 and the Tumon-Maui well.

As discussed above, ATSDR also evaluated all municipal drinking water wells near Andersen AFB. Only contamination in the MARBO Annex OU (specifically, two plumes in the Yigo Subbasin) has the potential to impact municipal drinking water wells. This contamination, however, has not been detected in active, downgradient municipal wells or in the water of the northern city of Dededo. Therefore, the public has never been exposed to VOC-contaminated drinking water via GWA wells.

ATSDR concludes that *no public health hazards* are associated with past exposures via municipal drinking water wells.

Current Exposure

Today, the affected wells, MW-2 and the Tumon-Maui well, are closed. In Andersen AFB's other production wells and in the distribution system, no contamination is being detected at or above ATSDR CVs or EPA's MCLs (Williams 1993). Therefore, drinking water from the military wells is not expected to pose a public health hazard. In addition no off-base GWA production wells or nearby private wells have contained TCE or PCE concentrations above ATSDR CVs for drinking water. VOC concentrations in the Yigo Subbasin have not increased and area drinking water meets federal standards. Therefore, ATSDR concludes that *no public health hazards* are currently associated with the ingestion of Andersen AFB, municipal drinking water, and private well water.

Future Exposure

The Air Force has installed air striping units that will remove VOCs from MW-2 and the Tumon-Maui water if and when the wells are restored to service (Earth Tech 1998). These activities, combined with other remedial and interim activities (see Appendix A), have eliminated potential future exposure pathways and potential sources of groundwater contamination. Furthermore, on-base drinking water quality will continue to be closely monitored and land use restrictions will regulate the installation of new wells in the annex (Montgomery Watson 1998). Therefore, ATSDR concludes that future exposures to drinking water from the Andersen AFB distribution system pose *no public health hazards*.

Off-base municipal wells potentially at risk for future contamination from Andersen AFB will continue to be monitored biannually. ATSDR found no indications that contamination levels will increase in the future. Furthermore, ATSDR was unable to locate any plans to construct new production wells within plume boundaries or in areas downgradient of plumes. It is highly unlikely that future wells will be situated in areas of known groundwater contamination. If wells were to be built, regulatory agencies would require cleanup of the groundwater to conditions that are acceptable for drinking. Therefore, ATSDR concludes that future exposures to GWA production well water pose *no public health hazards*.

Evaluation of Biota Exposure Pathway (Food Chain)

Conclusion

ATSDR concludes that no apparent public health hazards are associated with the consumption of locally grown produce or deer from Andersen AFB.

Discussion

Terrestrial Biota Use at Andersen AFB

People regularly consume papaya and other edible fruits grown on and off base, but access to on-base produce is limited. Some Guam residents recreationally hunt Sambar deer, wild pigs, and monitor lizards in areas around Andersen AFB (EA Engineering 1995; USAF 1993). Some hunters with permits may also hunt at Andersen AFB. People eat deer muscle, pig muscle, and pig skin tissues, but no reports indicate that people eat animal liver (the liver is generally the most highly contaminated tissue in an organism). No Guam residents surveyed during IRP investigations claimed to eat monitor lizard, but some individuals reportedly knew people who had eaten lizard muscle (EA Engineering 1995).

The only other edible macro-species present in Guam's northern limestone forest are the brown tree snake, Marianas Fruit bat, and the Philippine turtle-dove. Local residents do not eat brown tree snakes. ATSDR does not consider the consumption of bat and dove tissue to be likely human exposure pathways. ATSDR did not evaluate this consumption further, due to the limited numbers of these two species and the bat's protected endangered-species status (EA Engineering 1995; USAF 1993).

Terrestrial Biota Contamination and Potential Exposures

During the IRP, field investigators collected and sampled Sambar deer, wild pigs, monitor lizards, brown tree snakes, and papaya from areas on and off base (see Figure 6). Thirty-six chemicals (metals, pesticides, and semi-volatile organic compounds [SVOCs]) were detected in these samples. ATSDR evaluated these chemicals to determine if there are potential exposure pathways associated with the biotic transport of contaminants originating from Andersen AFB. Two contaminants, arsenic and aluminum, exceeded CVs (see Appendix D), and ATSDR estimated exposure doses and evaluated potential health hazards associated with these contaminants. Using highly conservative assumptions, ATSDR estimated human exposure doses from the consumption of local biota. Our estimated doses were below doses associated with adverse human health effects. Uncertainties surrounding evidence for arsenic and aluminum toxicity at such low-level environmental exposures strengthen ATSDR's

conclusion that there are *no apparent health hazards* (past, current, or future) associated with consumption of local biota.

Evaluation of Soil Exposure Pathway

Conclusion

ATSDR concludes that no public health hazards are associated with public exposure to contaminated soil at Andersen AFB.

Discussion

Military practices at various locations across Andersen AFB have resulted in spills or releases of chemicals to the surrounding ground surface (see Appendix A for site-specific data). The Air Force conducted environmental investigations to characterize the type and extent of contamination in the surface and subsurface soil at each site. ATSDR has used the Air Force's surface soil concentrations in this public health evaluation: the public is most likely to come in contact with the uppermost, or surface, layer of soil. (Please see Appendix A for the status of soil remediation action at each IRP site.) The type and extent of soil contamination are discussed below (by OU) and further summarized in Appendix A of this document.

Soil Monitoring Data

Main Base OU: The Main Base served as the Air Force's B-29 facility on Guam during World War II, as an ammunition storage area during the Korean War, and as a base for B-52 bombers and stratotankers during the Vietnam Conflict (USAF 2000). In support of these activities, the Air Force used landfills, cleaning operations, underground storage tanks (USTs), and fire training areas. Operations and waste handling practices at these locations released contaminants into the surrounding soil. Site investigations have revealed metals, SVOCs, polychlorinated biphenyls (PCBs), and pesticides in soil at many of the 23 IRPs located at the Main Base OU.

Some of the highest concentrations of metals were detected at the landfills, where lead was detected relatively frequently and at relatively high concentrations. For example, lead was detected at IRP 2/LF-2 (up to 8,300 ppm), IRP 5/LF-7 (up to 57,000 ppm), and IRP 10/LF-14 (up to 40,000 ppm)--at levels above EPA's soil screening value for children of 400 ppm. Other metals found in elevated concentrations include arsenic, chromium, and cadmium. IRP 2/LF-2 and IRP 5/LF-7 were used for sanitary trash disposal, while IRP 10/LF-14 stored construction debris (USAF 2000). Many of the areas are being further investigated to determine whether remediation will be required.

Northwest Field OU: The Northwest Field encompasses 4,387 acres on the northwest coast of Guam. During World War II, airfields on the land supported fighter planes and bombers. Since that time, the Air Force has deactivated the airfields and used the property for temporary housing, as a satellite control facility, and as a radar bombing scoring facility. The spills and releases caused by operations that supported the runways (including fuel storage, cleaning, and maintenance) are matters of potential environmental significance. The OU located in this area encompasses seven IRP sites, including four landfills (IRP 7/LF-9, IRP 16/LF-21, IRP 17/LF-22, and IRP 21/LF-26) that contain runway

construction debris, a waste pile (IRP 30/WP-4), a chemical storage area (IRP 31/CS-4), and a dump site (Ritidian Point). Also, the Urunao Dump sites are being proposed for investigation under this OU.

Monitoring revealed relatively high levels of metals in soil at IRP 16/LF-21, where past disposal of sanitary trash resulted in lead concentrations up to 27,000 ppm and chromium concentrations up to 6,500 ppm. Lead and chromium were also measured in soil at IRP 31/CS-4 at concentrations up to 3,100 ppm and 1,300 ppm, respectively. Lower concentrations have been measured at the other investigated landfills (IRP 17/LF-22 and IRP 21/LF-26) in this OU. The Air Force plans to remove contaminated soil from IRP 16/LF-21 and IRP 31/CS-4, and they have recommended no further action for IRP 7/LF- 9, IRP 21/LF-26, IRP 17/LF-22, and IRP 30/WP-4. Environmental investigations are still underway at the Ritidian Point dump site.

MARBO Annex OU: The MARBO Annex covers across 2,431 acres and has been used for administrative functions and base housing. The six IRP sites at the MARBO Annex OU include IRP 23/WP-5, IRP 22/WP-6, IRP 20/WP-7, IRP 24/LF-29, IRP 37/War Dog Borrow Pit, and IRP 38/MARBO Laundry. Metals and SVOCs have been detected in soil at the waste piles and IRP 24/LF-29. Again, lead was detected frequently and in high concentrations. Some of the highest lead concentrations in the OU were detected at IRP 20/WP-7 (18,000 ppm) and IRP 24/LF-29 (120,000 ppm) (USAF 2000). Remedial actions have been completed at the IRP 38/MARBO Laundry and IRP 20/WP-7, while remedial actions proposed in the MARBO Annex ROD have begun at IRP 24/LF-29 and IRP 22/WP-6.

Harmon OU: Harmon Annex sits on 1,817 acres and is the smallest area of the base. During World War II, Harmon Annex supported non-industrial functions, but industrial facilities were subsequently built on the land to support Korean War operations. Today, most of the buildings have been removed or abandoned. The area consists of three IRP sites: IRP 18/LF-23, IRP 19/LF-24, and IRP 39/Harmon Substation.

Soil sampling completed at the Harmon OU identified elevated levels of metals, including 13,000 ppm of lead at IRP 19/LF-24 and up to 940 ppm of lead at IRP 39/Harmon Substation. Much lower concentrations of metals and other contaminants were measured at IRP 18/LF-23. Contaminated soil was removed from IRP 19/LF-24 and IRP 39/Harmon Substation in July 1999. No cleanup of contaminated soil was warranted at IRP 18/LF-23 because further investigations indicated that the site may not have been used as a landfill (USAF 2000).

Evaluation of Public Health Hazards

Past and Current Exposures

Trespassers are potential receptors to Andersen AFB soil contamination.[(5)] They might come in contact with contaminants when handling soil or by inadvertently eating soil through hand-to-mouth activity. Inhalation of soil particles is not considered to be a significant source of exposure because all land on IRP sites is either extensively vegetated, paved, or enclosed.

ATSDR assumes that any soil contact would be with surface layers, since trespassers would be unlikely to dig on site. Moreover, any exposure would be infrequent and of short duration, because military

security measures prevent trespassers from accessing industrial areas and base facilities (places where IRP sites are located). Such minimal, infrequent exposure to on-site contaminants, if it occurs at all, would not be expected to result in adverse health impacts. In addition, most Andersen AFB sites display warning signs about site hazards which should prevent and/or reduce potential exposure to contaminated soil.

Future Exposure

What is radon?

Radon is a gas that is derived from the radioactive decay of radium, a natural element found in rock and soil. Radon gas can enter homes through building foundations and accumulate in indoor air.

There are no early signs of radon exposure because radon is imperceptible by odor, taste, and color, and causes no symptoms of irritation or discomfort. Only by measuring radon levels can people know whether they are being exposed to excessive levels of radon gas.

Future land use and accessibility of certain IRP sites will remain restricted due to institutional controls and deed restrictions, even if the Air Force returns its excess lands to the people of Guam. Note that certain sites are being remediated by the Air Force as a precautionary measure to prevent exposure to on-site workers and to prevent contamination from leaching into groundwater. These remedial actions are conducted with oversight by EPA and the GEPA to ensure protection of human health and the environment and are detailed or will be detailed in the RODs prepared by the base. In evaluating available monitoring data and proposed remedial actions, ATSDR has identified no past, current, or future public health hazards associated with contaminated soil.

Evaluation of Radon Exposure Pathway

Conclusion

Naturally occurring radon gas has entered certain on-site military housing units at levels that exceed EPA's guidance level of 4 pCi/L. People who live in these units could have been exposed to radon. The full extent of these exposures is unknown; therefore, ATSDR is not certain what potential public health hazards are associated with the exposures. The Air Force has mitigated radon at most of the affected housing units and plans to continue their sampling and mitigation efforts.

Discussion

Radon Monitoring and Mitigation Programs

Radon naturally occurs at high levels on Guam; it does not originate from military activities at Andersen AFB. Radon levels on Guam will fluctuate, even in a given building structure, primarily because the island's daily tremors constantly open and close ground fissures through which radon escapes (Bias 1999). Since 1987, the Air Force has conducted several monitoring programs to characterize radon levels in indoor air of on-base buildings.

Table 3 summarizes the findings of Andersen AFB's radon monitoring programs. In their initial study conducted in 1987 and 1988, the Air Force tested radon levels in 33 housing units. Results from this testing indicated that indoor radon levels of 18 units exceeded EPA's recommended action level for radon of 4 pCi/L (14 houses contained 4-20 pCi/L of radon and 4 houses contained 20-200 pCi/L of radon) (Bias 1999). Based on these results, EPA and the Air Force designated Andersen AFB "high risk," meaning that all habitable structures required sampling.

Following that determination, the Air Force conducted several broader monitoring programs to characterize the extent of radon contamination in all occupied housing units and in other public buildings across the base. In 1988 and 1989, the Air Force placed 1,754 radon monitors in all on-site housing unit for 60 days. Of the 1,754, monitors 1,406 were analyzed, with results showing that 74 houses contained 20-200 pCi/L of radon and 1 house exceeded 200 pCi/L of radon. All houses with radon above 20 pCi/L were mitigated and re-sampled until all radon gas concentrations were below 4 pCi/L. For 617 houses with radon 4 and 20 pCi/L, the Air Force deployed one-year monitors to verify that radon levels remained below 20 pCi/L (Bias 1999).

The Air Force conducted another round of monitoring in late 1989, which showed that about 40% of the tested structures (835 houses, 14 apartments, the Chapel pre-school, and the youth center) contained radon levels between 4 and 20 pCi/L and another 4% (84 houses and one apartment) contained levels between 20 and 200 pCi/L. The remaining structures contained radon at levels below EPA's recommended action level. (Air Force records suggest that 216 of the one-year monitors may never have been retrieved or analyzed.) Mitigation of the housing units was directed toward installing over-sized air conditioner fans to give the houses slightly positive pressure.

During ATSDR's February 1993 site visit, ATSDR identified radon as a potential contaminant of concern. Six months later, the Air Force retested the air in 1,390 military family housing units for radon levels. Of those units tested, 785 units were below EPA's recommended action level of 4 pCi/L of radon and required no mitigation; 743 units were above 4 pCi/L and were mitigated by Air Force contractors; and 124 units were above 20 pCi/L and were mitigated by the Base Civil Engineering Squadron. At this time, all the buildings considered most at-risk for radon contamination have been tested and mitigated as required to meet EPA guidelines, referenced in the 1988 Indoor Radon Abatement Act. Additional information can be obtained online at http://www.epa.gov/iaq/radon/pubs/index.html EXIT and at http://www.epa.gov/iaq/radon/ EXIT

The Air Force continued regular monitoring and mitigation of on-site structures into 1993 (Bias 1999). In August 1993, however, a large earthquake (measuring 8.2 on the Richter Scale) struck Guam and interfered with radon monitoring and mitigation efforts. Currently, a comprehensive database does not exist to link pre-earthquake sampling results and radon mitigation efforts with post-earthquake activities.

Without a comprehensive data set, the Air Force cannot readily determine if all on-site structures have been recently monitored, mitigated, and re-monitored as necessary. A statistical analysis of pre- and post-earthquake radon levels, however, indicates that radon levels in certain houses increased an average of 2 pCi/L after the earthquake.

In Andersen AFB's most recent radon monitoring program, conducted in July 1998, the Air Force collected 72 samples from a set of structures (37 houses and 35 non-house buildings) that lacked verifiable pre- and/or post-earthquake sampling and mitigation records. (Some of the homes had been previously renovated.) Of the 37 sampled houses, 26 houses contained less than 4 pCi/L of radon and 8 houses contained 4-20 pCi/L of radon (4.59 to 17.51 pCi/L). None of the homes contained radon at levels greater than 20 pCi/L. In 1999, the Air Force renovated three houses located on Okinawa Lane that contained elevated radon levels (between 4 and 17 pCi/L). It is assumed that the radon levels at these residences have since dropped, but the Air Force lacks confirmatory sampling data. Four of the five remaining affected houses were previously renovated (two houses in 1991, one house in 1995, and one house in 1997). The Air Force plans to reassess the radon levels and mitigation design at these houses.

Among the 35 buildings (non-housing units), 33 buildings contained radon at levels below 4 pCi/L. Only two buildings contained levels greater than 4 pCi/L: one facility building contained radon at 5.89 pCi/L and another contained radon at 43.57 pCi/L (Andersen AFB 1999b).

As of May 2000, 755 of the 1,390 housing units on base have been renovated (Andersen 2000).

Currently, the Air Force is evaluating its overall radon program to ensure that they have adequately evaluated the risk in each on-site structure. The Air Force plans to begin sampling of renovated homes in 2001 to test the adequacy of the mitigation efforts (Andersen AFB 2000a). ATSDR identified radon in indoor air as a past, current, and potential future completed exposure pathway for some on-base residents.

Evaluation of Public Health Hazards

ATSDR is unable to fully assess the potential health hazards associated with past radon exposure at Andersen AFB. The full extent of past radon exposure at Andersen AFB remains unknown due to limited historical sampling data and uncertainties about individual exposures. Additionally, ATSDR does not have a health-based comparison value for radon, and EPA has not identified a reference concentration. EPA's carcinogen assessment has been withdrawn (formerly thought to be a human carcinogen) pending review of additional information regarding the potential of radon to cause cancer in humans.

Toxicologic studies report that radon exposure causes no acute or subacute health effects. The primary health concern associated with residential radon exposure is lung cancer, although there is currently no clear evidence that radon exposure causes lung cancer. A recent report from the National Research Council estimates that approximately 1 in 7 of all lung cancer deaths can be attributed to radon exposure, independent of smoking status, though these estimates are uncertain (BEIR VI 1999).

Many factors influence the risk of lung cancer resulting from radon exposure. Among these are the radon level, the duration of exposure, the time since initiation of exposure, the age of an exposed individual, and the individual's smoking habits. The combined effects of cigarette smoking and radon exposure place current and former smokers at particularly high risk for lung cancer. Epidemiologic studies show that individuals working in certain industries susceptible to radon releases are at greatest risk, because they are often exposed to high levels of radon over an extended period of time. In one study, uranium miners exposed to radon levels of 50 to 150 pCi/L in air for about 10 years have shown an increased frequency of lung cancer (ATSDR 1990), though this study suffers from several weaknesses including lack of control for exposures to other agents that could contribute to lung cancer, such as silica and smoking.

ATSDR cannot determine with certainty whether the radon levels posed a past public health hazard for residents of Andersen AFB housing, but certain factors would suggest that the typical individual has a reduced likelihood of developing harmful health effects. They include:

- ***Limited period of exposure.*** Most residents of military housing reside on base for a 2-3 year period. This time period is much shorter than the duration of exposure reported for occupational studies in which workers developed health effects. Furthermore, the Air Force mitigation efforts have reduced radon levels and the potential for harmful health effects at the houses at greatest risk.

- ***Exposure to low air radon levels.*** Most tested buildings at Andersen AFB had radon levels below 50 pCi/L, the level associated with adverse health effects in workers.

The Air Force has been mitigating on-base housing levels of radon since 1989 and it plans to continue its radon testing and mitigation of residential units in 2001, as well as to expand its base program to other, lower priority buildings. The Air Force's continued commitment to mitigating naturally occurring radon in the housing units should greatly reduce current and future public health hazards from radon exposure.

Evaluation of Physical Hazards

Conclusion

Unexploded ordnance (UXO) exists in the Northwest field at Andersen AFB. To date, there have been no accidents involving UXO. Due to the implementation of educational programs, access restrictions and ongoing monitoring efforts, harmful contact with UXO is remote and does not pose a public health hazard.

Asphalt debris and exposed tar is located in the asphalt recovery area in the landfill complex. Access is restricted to the landfill complex. Trained workers entering the recovery area will be required to conduct activities in accordance with OSHA health and safety requirements, minimizing risk of health hazards.

Unexploded Ordnance

Unexploded ordnance (UXO) has been disposed of at IRP 17/ LF-2 and IRP 30/ WP-4, at the Northwest Field. The Northwest Field is restricted to public access, but certain areas are open to hunters with permits. There have been no recorded incidents of injuries resulting from encounters with UXO at Andersen AFB since the Air Force began disposing UXO at the landfills in the 1950s. Live UXO is dangerous and should be avoided. **If UXO is discovered, do not touch or tamper with it. Contact the Air Force Explosive Ordnance Disposal (EOD) Unit at (671) 366-5198**

There is a long history of people safely using areas cleared of UXO (QuantiTech 1997, Wilcox 1997). A nationwide study conducted by the U.S. Army Corp of Engineers (USACE) found no cases where people have been hurt upon encountering UXO. They found, however, that accidents occurred in cases where a trespasser removed the UXO and tampered with the item, or in cases of active disturbances, such as a worker digging into a buried UXO.

An encounter with a UXO item could possibly occur in the Northwest Field disposal areas. The probability of a hazardous encounter has been reduced through the current educational program and access restrictions at Andersen.

A recreational user of the Northwest fields may encounter UXO. It is unlikely that a harmful outcome would occur during an incidental encounter. However, prudence suggests that improved education, access restrictions, clear delineation of restricted areas and implementation of a monitoring plan will further reduce the likelihood of a future health hazard.

Exposed Asphalt Debris

Asphalt-containing drums left over from the construction of the Andersen's AFB runways and roadways during the early 1940s have been disposed of at IRP 35/W-1. The site spans 7 acres of the Main Base OU, away from residential and recreational property. Most of the drums at the site have deteriorated, allowing about 170,000 gallons of asphalt to empty onto the surrounding ground surface over time (Andersen AFB 1998a).

Cleanup at the site began in November 1997. The Air Force has cleared heavy vegetation, removed about 3,800 cubic yards of asphalt debris (primarily nonrecoverable asphalt soil) and then stockpiled the asphalt debris in drums on the ground at the site. Four-foot high soil berms now surround the piles. Also asphalt has been drained from about 8,000 recovered drums into six trenches that were dug into the limestone bedrock at the site. The 8,000 empty drums that once contained asphaltic material are stockpiled in the metal debris stockpile located on the northwestern portion of IRP 35/WP-1 (Andersen AFB 1998). The Air Force processed the asphalt in the trenches in an asphalt recovery system and then collected the recovered asphalt in more than 3,800 55-gallon drums.[(6)]

The exposed asphalt debris still remains at IRP 35/WP-1 as the base is awaiting the results of an impending pilot field study intended to identify appropriate landfill handling procedures (Andersen AFB 1998). Trespassers could enter the area and contact the exposed debris or asphalt remaining in the trenches since the area lacks signs or barriers to restrict public access.

Asphalt in the drums is a mixture of aggregate, sand, filler, bitumen, and occasionally a number of other additives. Some occupational studies have noted a higher than average rate of skin damage, such as

reddening, blistering, or peeling, among people who produce or apply asphaltic material (ATSDR 2000). ATSDR is not aware of any studies that suggest that incidental contact with asphalt debris causes health effects. Trespassers could conceivably contact the material but in all likelihood the exposure would be brief and infrequent because the base's security measures prevent trespassers from accessing industrial areas. In addition, this area is located far from residential and recreational property.No apparent public hazards have occurred in the past or are likely to occur now or in the future from trespasser exposure. Trained workers entering the recovery area will be required to conduct activities in accordance with OSHA health and safety requirements, minimizing risk of health hazards. Institutional controls such as controlled access and more visible warning signs should be adequate to prevent access by uninformed or unauthorized visitors to the area where they might encounter the exposed asphalt or asphaltic debris.

COMMUNITY HEALTH CONCERNS

Andersen AFB has a community relations plan (CRP) that provides guidance for involving the community and other interested parties in the remediation decision making process and for distributing information to these parties (USAF 1998). As part of its community relations activities, Andersen AFB has formed a restoration advisory board (RAB). The RAB, which is represented largely by local community members, meets periodically to review site documents and comment on Andersen AFB remedial actions. Through the public health assessment process, ATSDR has gathered information about health concerns identified in the CRP or voiced by community members at RAB meetings. Following is a summary of the community health concerns that have come to ATSDR's attention.

Concern: *Why is ATSDR assessing the site after cleanup activities have begun at the site?*

ATSDR's involvement at Andersen AFB focuses on public health (i.e., the health impact on the community as a whole). In evaluating potential public health hazards, ATSDR reviewed available environmental data, both available pre-and post remediation data, as well as any proposed remedial actions. Our review of the available data shows that *people have not come in contact with, nor are they expected to contact, hazardous substances from Andersen AFB at levels posing potential public health hazards*. Therefore, based on the available data, regardless of the stage of investigation, contamination from Andersen AFB poses no public health hazard. ATSDR is an advisory agency, so if hazards were identified, the PHA would recommend appropriate actions, such as additional cleanup measures, to be undertaken by responsible parties.

Site characterization and remediation at NPL sites may continue for years after releases are suspected. Likewise, remediation may occur before or after ATSDR's involvement begins. Sometimes, additional data are generated after remediation and after a PHA has been released to the public. In such cases, the PHA is updated. Therefore, if new data are collected or additional information is compiled that suggest the public health may be adversely affected as a result of or despite proposed or completed cleanup action, ATSDR will modify or add to the document in a way to reflect the public health implications of the additional data and recommend actions to stop or reduce exposures in its public health action plan.

Concern: *Will land returned to the government of Guam be safe for public use, particularly land occupied by IRP 20/WP- 7?*

Land transferred to the government of Guam will be either required to be free of harmful levels of contaminants specific to its intended use or encumbered with deed restrictions that indicate how the land can be safely used in the future. As noted earlier, land occupied by IRP 20/WP-7 will be transferred in the future to the government of Guam for public use. Due to past site operations, however, soil at this location has become contaminated with metals, PCBs, and pesticide waste. The risk to humans is primarily driven by elevated soil lead concentrations. Certain surface soil samples exceeded EPA's guidance level for lead in soil (400 ppm), while deeper soil samples (greater than 12 feet) showed much higher levels. Left exposed or if disturbed, the lead-contaminated soil could pose an unacceptable risk for people who might routinely come in contact with the contaminated soil in the future.

The Air Force has placed a soil cover over the area to reduce the potential exposure of future users to high levels of lead in soil. Deed restrictions accompanying the transfer of the land will ensure that the land will be used in such a way to maintain the integrity of the soil cover and to minimize soil disturbances. Examples of non-intrusive future land uses proposed for the area include the operation of a non-residential maintenance yard or several storage areas.

As a reminder, ATSDR's goal at Andersen AFB is to evaluate whether any past, current, or future exposures could result in public health hazards. It is important to note that even though soil beneath Waste Pile 7 contains lead, a public health hazard can exist only if people come in contact with harmful levels of contamination. By following the land use restrictions and respecting the soil cover, ATSDR concludes that people should not come in contact with lead-contaminated soil from Waste Pile 7. However, as a precautionary measure ATSDR highly recommends that the deed restrictions stipulate that the land not be used by or for children (a population very susceptible to lead poisoning) and that the Air Force ensures the integrity of the soil cover at Waste Pile 7 before transferring the land to the government of Guam.

ATSDR understands that certain individuals may wish to use the land in ways other than those specified in the Air Force's deed restrictions. If deed restrictions do change or if the soil cover is removed or disturbed at some point in the future, ATSDR recommends that this potential exposure pathway be reevaluated.

Concern: *Have toxic chemical warfare agents been used or stored at Andersen AFB, and, if so, do they still exist in areas accessible by the public?*

Chemical warfare materiel were used and stored at Andersen AFB, but no information has been found describing bulk use, storage, release, or disposal of ***toxic*** chemical weapon agents, such as mustard gas or nerve agents. In reviewing site history and talking with site representatives about Andersen AFB, ATSDR learned that toward the end of World War II, the land now occupied by Andersen AFB served as an important operations center for military action in the Pacific theater. In supporting wartime activity, chemical warfare materials were used or stored at Andersen AFB but were limited to material necessary for the supply and operations of smoke generators and flame throwers. These types of materials are not considered to be toxic. There are no indications that bulk toxic chemical warfare materiel was ever sent to Guam in the documentation reviewed. Rather, bulk toxic munitions were commonly stored on the west coast of the United States and in Hawaii during World War II, and then on Japan during the Korean War (Hart Crowser 2000).

In 1978, the Army undertook an investigation to locate and remove chemical agent identification sets (CAIS) from 15 military installations nationwide, including Guam. The kits would have been used to identify enemy chemical warfare agents. It is believed that the military staff ordered the kits for toxic gas identification training exercises. The Army investigators found an unknown quantity of CAIS, known as K951:War Gas Identification Sets, Instructional M1, and then transported the sets by airplane from Guam to Rocky Mountain Arsenal. Intact glass vials within the CAIS sets were found to contain diluted amounts of mustard gas, CG, lewisite, and PS. No nerve agents were found in these kits.

What should I do if I find CAIS on my property?

1. **Retreat** from the area. Don't touch it!

2. **Report** discoveries of the CAIS kits in the Northern portion of Guam to the Air Force Explosive Ordnance Disposal (EOD) Unit at (671) 366-5198 and discoveries in the southern portion of Guam to the Navy EOD at (671) 339-8156.

In July 1999, 16 additional CAIS were found buried in a field on a privately-owned farm near the village of Mong Mong. A team of representatives from EPA, the Army, Air Force, and Coast Guard removed the World War II era canisters and transported them to a temporary storage facility at Andersen AFB before final transport to Johnson Atoll for disposal. The land was used toward the end of World War II for a Navy ammunition depot. It is believed that these canisters contained CAIS.

Based on preliminary information available, it is highly unlikely that people have been or could be exposed to chemical agents or other hazards from these canisters. *The canisters were found intact, suggesting that no release of chemicals to the environment occurred from the time the canisters were buried until they were removed.* Furthermore,all kits discovered have been removed, so current and future exposures from discovered kits have been prevented. The USACE will survey the property for remaining canisters using metal detectors and ground penetrating equipment. Additional cleanup may be necessary depending upon their findings.

The discovery of these canisters suggests that the burial of canisters might not be an isolated incident and that other canisters could be buried elsewhere on Guam. The military has procedures in place to properly handle buried containers should they be discovered in the future (during the course of environmental remediation, for example). As a reminder, the chemical agents in CAIS kits can be toxic and should be handled only by trained individuals. Community members discovering suspected CAIS kits or related materials should not remove or further disturb the area. Rather, discoveries of the CAIS kits in the northern portion of Guam should be reported to the Air Force Explosive Ordnance Disposal (EOD) Unit at (671) 366-5198 and discoveries in the southern portion of Guam should be reported to the Navy EOD at (671) 339-8156.

ATSDR CHILD HEALTH INITIATIVE

ATSDR recognizes that infants and children may be more sensitive to exposures than adults in communities with contaminated water, soil, air, and food. Children are more likely to be exposed to soil or surface water contamination because they play outdoors and often bring food into contaminated areas. For example, children may come into contact with and ingest soil particles at higher rates than adults do; also, some children with a behavior trait known as "pica" (frequent hand-to-mouth behavior) are more likely than others to ingest soil and other nonfood items. Children are shorter than adults, which means they can breathe dust, soil, and any vapors close to the ground. Also, they are smaller, resulting in higher doses of chemical exposure per body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages. ATSDR is committed to evaluating their special interest at sites such as Andersen AFB, as part of the ATSDR Child Health Initiative.

It is estimated that there are about 2,100 children living on the base. Enrollment at the elementary and middle schools on the base is 1,137. Enrollment at the Guam Elementary/Middle School and Guam High School is 668 and 3785 students, respectively (Andersen AFB 2001).However, these children/students are not exposed to contamination because access to contaminated areas is restricted and blocked by fencing. Thus, no past, current, or future health hazard is posed to children attending school on or near the base.

Data on the effects of radon exposure in children are limited. Differences in lung structure and breathing rates in children result in higher estimated doses that may make children more susceptible to the effects of radon than adults (Samet et al. 1989). Children also have a longer latency period ahead of them in which to develop cancer. However, there are currently no conclusive data on whether children are at greater risk than adults from radon exposure. Child exposure to radon in Andersen AFB housing units appears limited (a maximum exposure of approximately one or two years) because the families of active-duty Air Force personnel frequently move. Air Force personnel are taking active measures to reduce radon levels in base housing. There does not appear to be a public health hazard from radon exposure to children living in base housing.

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2. ATSDR found no relevant information describing potential environmental impacts that Andersen AFB activities may exert on the Mangilao Subbasin. This document, therefore, does not further discuss that Mangilao Subbasin.
3. Fern Lake provides an additional source of water for Guam, primarily for use by the Navy (Earth Tech 1998).
4. Note that the IRP well number does not necessarily match the IRP unit in which it is located.
5. On-site workers are also potential receptors, but ATSDR assumes that Occupational Safety and Health Administration requirements adequately protect the health of workers when they are on the job. On-site workers at Andersen AFB are not, have not been, and will not be exposed to contaminated soils except as part of their normal work responsibilities and material handling. Therefore, this public health assessment focuses exclusively on trespassers' exposure to contaminated soils.
6. Although no soil was removed, the Air Force took 10 "confirmatory" soil samples from the area. The results indicated that SVOCs and PAHs concentrations were safely below standards for residential and industrial uses. Metals, including aluminum (up to 220,000 ppm), chromium (1,340 ppm), and manganese (3,370 ppm) were detected at levels above EPA Region's 9 residential or industrial soil standards of 100,000 ppm for aluminum, 450 ppm for chromium, and 3,100 ppm for manganese.

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LIST OF ABBREVIATIONS

ABW	Air Base Wing
AFB	Air Force Base
AOC	area of concern
ATSDR	Agency for Toxic Substances and Disease Registry
CAIS	chemical agent identification sets
CCl_4	carbon tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CRP	community response plan
CV	comparison value
DCA	1,2-dichloroethane
DOD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
ESI	Expanded Source Investigation
FFA	Federal Facility Agreement
FS	feasibility study
GEPA	Guam Environmental Protection Agency
GPZ	groundwater protection zone
GWA	Public Utility Agency of Guam
IRP	Installation Restoration Program
kg	kilogram
MARBO	Marianas Bonins Command
MCL	EPA's maximum contaminant level
mg/kg/day	milligrams per kilogram per day
MRL	ATSDR's minimal risk level
MW	military well
NA	not applicable
ND	not detected
NPL	EPA's National Priorities List
OU	operable unit
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene

pCi/L	picocuries per liter
PHAP	public health action plan
POL	petroleum, oil, and lubricants
ppb	parts per billion
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
RfD	EPA's reference dose
RI/FS	remedial investigation/feasibility study
ROD	Record of Decision (ROD)
SDS	storm drainage system
SVOC	semi-volatile organic compound
TCA	1,1,1-trichloroethane
TCE	trichloroethylene
TPH	total petroleum hydrocarbons
UST	underground storage tank
UXO	unexploded ordnance
VOC	volatile organic compound
WDBP	War Dog Borrow Pit

Next Section