Ambient Air Monitoring of the Beneficial Use of Municipal Waste Combustor (MWC) Ash as Daily Landfill Cover

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INTRODUCTION

This paper summarizes Human Health Risk Assessments of the proposed use of combined ash from the H-Power municipal waste combustor (MWC) in two beneficial uses: (1) Landfill Daily Cover for the Waimanalo Gulch Sanitary Landfill in Ewa, O'ahu, Hawai'i, which is operated by Waste Management of Hawaii, Inc.for the City and County of Honolulu and (2) Landfill Final Cover, a component in the final cover of the Waipahu landfill, in Waipahu, O'ahu, Hawai'i.

The human health risk assessment represents one phase of a larger project involving the investigation of several potential uses of H-Power MWC ash as alternatives to the current practice of disposal in a lined monofill located at the Waimanalo Gulch Sanitary Landfill. The ash consists of approximately 70% bottom ash and 30% fly ash from the MWC, hereafter referred to as H-Power combined ash.

At this time, three alternative uses of H-Power combined ash have been identified: The first option consists of using H-Power combined ash as a component in the final cover in the closure of the Waipahu Landfill; the second option consists of using H-Power combined ash as daily cover at the Waimanalo Gulch Sanitary Landfill; and, the third option consists of mixing H-Power combined ash into aggregate to be used in roadway paving material.

Investigations into these proposed ash uses are detailed in a September 1994 report which presents the rationale for and results of tests conducted to support alternative ash use as landfill cover (daily cover and final cover) and as roadway aggregate.[1] The tests conducted for this Phase I investigation included biological, chemical, and engineering tests (*e.g.*, botanical growth potential, metals content, sieve analyses, strength analyses, permeability, and others). The results of the Phase I investigation indicate that H-Power combined ash is suitable for these alternative beneficial uses.

During June 1995, subsequent to completion of the Phase I investigation, ambient total suspended particulate (dust) concentrations were measured at Waimanalo Gulch Sanitary Landfill during disposal of municipal solid waste (MSW) as well as disposal of H-Power combined ash into the lined monofill. The purpose of collecting these preliminary data was to estimate an emission factor for the combined ash. These data, together with the chemical data collected during Phase I, were used as the basis of human health risk assessments conducted for both landfill cover options (final cover and daily cover).

The human health risk assessment of the use of H-Power combined ash in the closure of the Waipahu Landfill was conducted by Ogden, and a report was submitted to the State of Hawai'i Department of Health (DOH).[2] Preliminary review by the DOH indicated that they approve of the methodology and procedures used therein.

Following this, Ogden prepared a preliminary human health risk assessment of the use of H-Power combined ash as alternate daily cover at the Waimanalo Gulch Sanitary Landfill. Based on chemical analytical data for ash samples collected during the Phase I investigation and other testing, noncarcinogenic and carcinogenic health effects were evaluated for ten constituents. Potential exposures to ash, ash-derived dust, and ash leachate were evaluated for key potential receptors, including landfill workers, adults and children who may visit the landfill (to dispose of household waste), and adults and children who live in nearby residential neighborhoods.

Several activities associated with the proposed use of H-Power combined ash as daily cover theoretically have the potential to create fugitive dust and, therefore, were evaluated in the risk assessment. They include:

- pushing and compacting fresh MSW on the previous day's ash cover;
- pushing and compacting fresh MSW on MSW;
- pushing and compacting fresh combined ash on MSW to create the daily cover; and,
- mining of combined ash.

The ambient air data collected in June 1995 (downwind of combined ash disposal in a lined monofill and MSW disposal in the lined landfill) were used as surrogate data for the dust concentrations associated with these specific activities. However, each of these activities has a different potential for dust generation and, at the time of the preliminary risk assessment, each was expected to produce different downwind dust concentrations. The 1995 dust data were used because activity-specific dust concentrations had not yet been measured. Analytical data generated from ash samples collected during the Phase I investigation and other testing were used to evaluate potential direct exposures to H-Power combined ash (ingestion and dermal contact), to predict leachate concentrations, and as mentioned, to estimate metals concentrations in dust. The results of this preliminary risk assessment were presented in a report to the Hawai'i and indicated that the proposed use of H-Power combined ash for daily cover would pose no significant noncarcinogenic or carcinogenic human health risk.[3]

The preliminary risk assessment for ash use as daily cover identified the lack of available air data associated with specific landfill activities. To address this data gap, approval was sought and obtained from the DOH to conduct a one-week demonstration program involving use of H-Power combined ash as alternate daily cover at the Waimanalo Gulch Sanitary Landfill. This demonstration program was conducted with the cooperation of the City and County of Honolulu, Waste Management of Hawaii, Inc., and the DOH.

These results were incorporated into the final human health risk assessment of the use of H-Power combined ash as alternate daily cover for the Waimanalo Gulch Sanitary Landfill. The revised risk estimates for the daily cover risk assessment are reported in this paper.

AMBIENT AIR MONITORING PROGRAM

During the one-week demonstration program, conducted during July 1996, concentrations of dust, metals, and crystalline silica were measured. Specifically, total and respirable dust, total and respirable metals (including arsenic, barium, chromium, cadmium, lead, nickel, selenium, and silver), respirable crystalline silica, hexavalent chromium, and total mercury (particulate and elemental vapor) were measured. Personal sampling was conducted in equipment cabs and on outdoor employees, and ambient sampling was conducted in numerous locations upwind and downwind of specific landfill activities. Overall, more than 100 personal and area samples were collected using personal sampling pumps, and more than 400 analyses were performed.

Ambient air samples were collected during dumping of ash into stockpiles (for use as daily cover), pushing and compacting of MSW on the previous day's ash cover, pushing and compacting of MSW on fresh MSW (current day's waste), and creating the daily cover at day's end. Data collected during the overnight period when the ash cover was exposed to the elements was evaluated separately. In addition to these daily

activities, air samples were also collected during the excavation of H-Power combined ash previously disposed in the landfill's ash monofill and subsequent loading onto dump trucks (referred to as ash mining).

At certain stations, all-day samples were collected. Locations included: OSHA U (upwind), OSHA D (downwind), CAT (in cab of caterpillar tractor), COMP (in cab of compactor), and SPOT (either on spotter or in spotter area). At other stations, designated ambient stations, samples were collected during four specific time periods defined as shifts 1-4 (S1-S4). These shifts corresponded to early morning, mid-day, late afternoon, and overnight. Ambient locations included: Ambient U (upwind), Ambient D1, Ambient D1A, Ambient D2, and Ambient D2A. In addition, a station designated ASH DUMP was established near to and directly downwind of the daily piles of H-Power combined ash that were dumped during the day for use as daily cover at day's end. Finally, on one day, a demonstration of ash mining in the ash monofill area was monitored. Station ASH MINE DUMP was established directly downwind of the operation, and station ASH MINE LOADER was on the window of the front end loader which loaded ash into dump trucks.

The analytical results from the demonstration program indicate total dust concentrations ranged from 50 to 1,400 $\mu g/m^3$, and respirable dust ranged from 30 to 840 $\mu g/m^3$ (see Tables 1 and 2). The ratio of respirable dust to total dust was calculated for each sample location where both were detected. The average ratio of respirable to total dust was 0.38 from 10 samples collected inside equipment cabs, and 0.24 from 30 outdoor ambient samples.

Arsenic, cadmium, chromium (total and hexavalent), mercury, lead, selenium, and silver were not detected in any of the total or respirable dust samples tested. Barium was detected in one total dust sample (at the detection limit of 0.0002 mg/m^3) but was not detected in any respirable dust samples. Similarly, nickel was detected in two total dust samples (at the detection limit of 0.0002 mg/m^3) but was not detected in any respirable dust samples.

Meteorological Observations

An on-site meteorological station was installed on the top of the hill at monitoring station D2A. Wind direction and wind speed data were collected for 15 minute average time periods. Windroses were developed for each monitoring period of interest so that it could be determined if a station was up-, down-, or cross-wind from a potential source during each specific time period.

The wind roses indicate that regional wind direction was generally from the north, northeast, and east directions during the monitoring period. Thus, the OSHA Upwind and Ambient Upwind stations were generally upwind of the working face at all times. The OSHA Upwind station was generally upwind of the ash piles at all times. The OSHA Compactor, Caterpillar operator, Spotter, and Downwind stations were generally downwind of the ash piles and the working face at all times. The Ambient D1/D1A stations were generally downwind of the ash piles and the working face at all times. Lastly, the Ambient D2/D2A stations were generally down- to cross-wind of the ash piles and the working face.

A simple evaluation of the OSHA eight hour samples indicates that a source other than the working face of the landfill or the ash piles is the likely source of the dust. For instance, on July 10, the total dust was highest in the upwind location and lowest directly on the working face. Respirable dust was also higher in upwind than downwind locations.

Similarly, on July 11, total dust was highest in the upwind location and lowest on the spotter. Respirable

dust was similar in upwind and downwind locations. Also, on July 12, total dust was similar in the upwind location and the spotter location. Respirable dust was greater in the upwind location than in downwind and spotter locations.

A similar evaluation of the ambient monitoring results also strongly suggests that the H-Power combined ash was not the source of the dust. Stations D1/D1A are clearly downwind of the ambient upwind location, and the latter is generally upwind of the ash piles and the working face. There is a trend of the upwind location having higher dust measurements. Out of 8 respirable dust values, 5 were higher in ambient upwind samples than in D1/D1A samples, with the average ratio being 9-fold. Out of 13 total dust measurements, 8 were higher in ambient upwind samples compared to D1/D1A samples with the average ratio being 2-fold. This again suggests that the source of the dust is not the ash piles or the working face.

Comparison of Results During Different Activities

If the ash were a source of dust, the time when most ash-derived fugitive dust would be created would have been during the S1 period when the compactor was operating atop ash and the S3 period when the compactor was creating the day's cover with ash. Measured dust during the S3 period was not elevated. In all samples from ambient downwind locations, no respirable dust or total dust was detected with detection limits of ~0.2 mg/m3. These data indicate that the spreading and compacting of H-Power combined ash to construct a daily cover does not create a significant amount of dust.

In addition, measured dust during the S1 period when the compactor was running over ash was not elevated compared to the S2 period when the compactor was generally running on fresh MSW. (On some days, the ash was not completely covered by the start of the S2 period, but it is still true that the compactor was on ash a greater fraction of the period during S1 than during S2.) Out of 28 samples (respirable dust and total dust) that had a detected value in at least one of the time periods (S1 and S2), only 7 were higher in S1 than in S2. For most of the samples (21/28), the values during S2 were higher than during S1. For this analysis, 1/2 the detection limit was used as a surrogate value for nondetects. In fact, in 17 of the 28 data pairs, dust was not even detected during the S1 period. These data indicate that the running of a heavy compactor over a landfill face covered with H-Power combined ash does not create a significant amount of dust.

The Ashdump sampling station was downwind of the OSHA Upwind station and downwind of the ash piles. The OSHA Upwind station was upwind of the ash piles. In every case (7/10, 7/12, and 7/14), the 8-hour OSHA Upwind sample was higher in respirable dust and total dust than the ashdump sample (by a factor of ~ 5 fold). This suggests that the ash pile itself was not the source of the dust monitored in the Ashdump samples.

Ashmining was also shown not to produce significant dust. No dust was detected at the ambient station placed downwind of the operation. Respirable dust was detected in the cab of the loader as would be expected. Small dust clouds were also visually observed when the loader dumped ash into the trucks.

A comparison of sampling locations where dust was detected with meteorological data concurrently collected during the demonstration program strongly suggests that the H-Power combined ash is not the source of dust concentrations observed. Lastly, it was observed during the demonstration project that running heavy equipment in and atop H-Power combined ash did not generate elevated dust levels, and therefore, typical landfill activities were grouped together and collectively evaluated as "daily activities".

HAZARD IDENTIFICATION

H-Power combined ash samples have been analyzed for several inorganic parameters as well as dioxin/furan congeners. TCLP metals data are available for combined ash samples collected between approximately 1989 and 1996. In addition, total metals analyses have included aluminum, arsenic, barium, cadmium, calcium, chromium, copper, iron, lead, mercury, nickel, potassium, selenium, silver, and zinc. From this list of constituents, aluminum, calcium, copper, iron, potassium, and zinc were eliminated from evaluation in the risk assessment because they have very low toxicity and/or are essential human nutrients. The remaining constituents were evaluated in the risk assessment.

The final list of chemicals of potential concern (CPC) includes the following metals: arsenic, barium, cadmium, chromium, lead, mercury, nickel, selenium, and silver (see Table 3). Furthermore, with the exception of nickel, these are the metals required to be tested by the Resource Conservation and Recovery Act (RCRA). Nickel was included because it is often defined as a chemical of concern for risk assessments of combustors. In addition to these metals, dioxin/furan congeners were also included in this risk assessment because they have historically been the focus of risk assessments of MWC facilities.

TOXICITY ASSESSMENT

Cancer slope factors, Reference Doses, and Reference Concentrations for all CPCs were obtained from standard EPA sources.[4,5] However, there is currently no EPA-verified Reference Dose for lead. Risk assessments for lead commonly use models of varying complexity that predict blood lead levels, which are then compared to benchmark levels of blood lead. The benchmarks have been determined by regulatory agencies to present no significant risk of harm. Because the U.S. EPA model can only predict blood lead levels in children, the Hawai'i Department of Health requested that the California DTSC model be used for this risk assessment.

The major components of the DTSC model were used as presented in DTSC guidance.[6] Specifically, the intake-blood lead slope factors (termed "constants" in the DTSC model) were not modified. However, several of the soil-specific default exposure parameters were modified as allowed by DTSC guidance, so that they were applicable to the assessment of human health risks posed by lead in *ash* versus residential soil. In addition, site-specific information on background lead exposures from air, water, and food was incorporated.

A review of the recent literature revealed that the lowest current regulatory blood lead limit for adults was 25 µg/dL.[7-13] This value was used as the benchmark for risk assessment of adult worker exposures in this analysis. The benchmark for young children and adult females of childbearing age was defined as 10 ug/dL.

EXPOSURE ASSESSMENT

The exposure assessment is presented separately for the Landfill Daily Cover Project (Waimanalo Gulch Sanitary Landfill) and the Landfill Final Cover Project (Waipahu Landfill).

Landfill Daily Cover (Waimanalo Gulch Sanitary Landfill)

It is proposed that H-Power combined ash be used for daily cover of the working face at the Waimanalo Gulch Sanitary Landfill. It is assumed that the daily cover would involve the placement and compacting of H-Power combined ash to a depth of approximately 6 inches over the working face of the landfill. This is assumed to require an 18 inch thickness of uncompacted ash. The risk assessment assumes that the dimensions of working face are approximately 55.5 m by 20.7 m, or 1,149 square meters (12,350 square feet). This was based on actual measurement of the working face during the July 1996 demonstration project.

The risk assessment assumes the amount of H-Power combined ash required for daily cover at the landfill is 686 cubic yards per day. H-Power currently produces approximately 300 cubic yards of combined ash per day. Since H-Power ash has been landfilled at the Waimanalo Gulch Sanitary Landfill for many years, the remaining amount needed for daily cover during the demonstration project, 354 cubic yards, was mined from the previously landfilled H-Power ash. For conservative purposes, it is assumed that the daily cover is 100% H-Power combined ash, supplied by current H-Power operations as well as by mining of the previously landfilled ash.

Ash was mined during the demonstration project from July 9 - July 13. Mined amounts ranged from 360 tons/day to 900 tons/day, with the average amount mined per day being 504 tons. No ash was mined on July 14. Deliveries of unprocessed combined ash during the demonstration project averaged 332 tons/day, which corresponds to approximately 332 cubic yards per day.

It is proposed that the ash will be processed before using it for daily cover of the working face at the Waimanalo Gulch Sanitary Landfill. Ferrous and nonferrous metals will be removed and the water content of the ash will be adjusted to a moisture content of approximately 25%. The estimated volume of processed ash produced per day is 176 cubic yards (214 tons/day /1.215 tons/cubic yard). Thus, the daily requirement for processed combined ash exceeds the production rate for a working face of 12,350 square feet. In the future, it is proposed that the remaining need for daily cover be mined from the previously landfilled ash. Also, the working face is often as small as 6,000 square feet. Daily production of H-Power combined ash would be sufficient to provide daily cover for this size working face, and no ash mining would be required.

The use of H-Power ash as daily cover assumes the following activities: In the morning (0700-1000 hours), workers push and compact municipal solid waste (MSW) over the previous day's ash cover. This ash has been exposed to the air for 14 hours and may have a lower moisture content than fresh H-Power ash. During the mid-day (1000-1500 hours), workers push and compact MSW over MSW deposited earlier the same day (*i.e.*, by this time, the previous day's ash cover has been covered with the current day's MSW, on top of which additional MSW is placed). During this time period, the workers are not running equipment atop of H-Power ash. During the late afternoon (1500-1700 hours), the workers are pushing and compacting ash over the fresh MSW to create the day's cover. This ash is fresh ash, which has a high moisture content. Then, this cover is exposed to the elements during the evening and night (1700-0700 hours). In addition to the daily operations described above, mining of H-Power ash previously disposed at the Waimanalo Gulch Sanitary Landfill is conservatively assumed to take place throughout every workday (0700 - 1700 hours).

Landfill Final Cover (Waipahu Landfill)

It is proposed that H-Power combined ash be used as the bottom layer of the final cover in the closure of

the Waipahu Landfill. This risk assessment assumes that the landfill area to be covered is 43 acres. It is assumed that the closure as proposed would involve the placement and compacting of 24 inches of H-Power combined ash and then 18 inches of local soil. The total amount of H-Power combined ash required to cover 43 acres to a depth of 24 inches is 138,746 cubic yards.

It is proposed that the H-Power combined ash be used as it is produced and processed. Each day's production of ash would be transported to the Waipahu Landfill, placed, compacted, and covered with local soil. The risk assessment addresses potential exposures that might occur during the period when the ash is proposed to be placed, compacted and covered at Waipahu Landfill and during the post-closure period.

The Waipahu Landfill is located adjacent to West Loch of Pearl Harbor with a small residential area to the northwest of the landfill. Accordingly, the risk assessment evaluates potential exposures that might occur in these areas. In addition, there is another residential area towards the southwest of the facility. Exposures in this area are also evaluated. In addition, risks posed by contact with surface water, sediment, and fish in West Loch are quantitated.

The risk assessment evaluated three potential scenarios regarding the manner in which the H-Power ash would be used as part of the landfill closure. In the first, it is assumed that the H-Power ash is delivered to Waipahu Landfill during the week and diverted to Waimanalo Gulch over the weekend. Deliveries only occur during the daylight hours. During the week, ash is stored at the H-Power Plant in covered trailers overnight and delivered to the landfill each morning. At the end of each day, it is assumed that the ash is spread, compacted, and covered with soil. This scenario is referred to as "Closure-No Stockpile" throughout the risk assessment.

In the second scenario, it is assumed that all of the combined ash is delivered to the Waipahu Landfill. Again, however, deliveries only occur during daylight hours (10 hours/day). Overnight during the week, it is assumed that ash is stored in covered trailers at the H-Power plant. During the weekend, the ash is continued to be delivered throughout the day on Saturday and Sunday, thus creating a temporary stockpile at the site that is spread, compacted, and covered with Mililani soil on Monday of each week. At the end of each day, it is assumed that the ash is spread, compacted, and covered with soil. This scenario is referred to as "Closure-Stockpile" throughout the risk assessment.

In the third scenario, it is assumed that the amount of ash delivered daily is spread and compacted, but it is not covered with Mililani soil at the end of the day. It is assumed that the day's ash delivery dries somewhat and can become entrained into the air as fugitive dust overnight before it is covered with soil on the next day. This scenario is referred to as "Closure-Uncovered" throughout the risk assessment.

After closure, it is possible that the Waipahu Landfill will be converted to a soccer field, a softball field, or a picnic area. There is no possibility that the ash can cause airborne dust or surface water run-off, however, because the ash will be covered with 18 inches of native soils. The landfill will also be vegetated. Accordingly, a Post-Closure scenario was defined in which the ash was disrupted so that there was a mechanism by which ash-derived dust and surface water run-off could be created.

For this scenario, it is assumed that dirt bikers have disrupted the integrity of the vegetated cover. It is assumed that this disruption has resulted in 10% of the landfill area (17,402 square meters) becoming unvegetated and thus subject to surface run off. It is also assumed that 2% of the landfill area (3,480 square

meters) has been compromised to the extent that H-Power combined ash is exposed at the surface and subject to dust generation in addition to surface run off. This scenario is referred to as "Post Closure" throughout the risk assessment.

Identification of Receptors

Potential human receptors were identified for on-site and offsite scenarios on the basis of land use information (see Table 5). For the landfill daily cover risk assessment, receptors were identified on-site and offsite at the nearest inhabited location to the south of the site. For the landfill final cover risk assessment, potential human receptors were identified for each closure and post closure scenario. Receptors were identified on-site, off-site at the nearest inhabited locations to the north and south of the site (in the direction of both Trade and Kona Winds), and at locations where relevant activities such as fishing or swimming could occur.

Exposure Point Concentrations

Total metal concentrations in H-Power combined ash are used as exposure point concentrations for the ash, itself (see Table 3). Data from TCLP analyses are used as estimates of chemical concentrations in ash leachate (see Table 3).

On-site and off site receptors may be exposed to chemicals of potential concern in ash via inhalation of fugitive dust generated by placement, grading, and compacting of ash, as well as fugitive dust generated by wind erosion of uncovered ash placed in piles or placed in a layer over a portion of the area of either landfill. The on-site concentrations of fugitive dust generated by various ash use activities were directly measured during the two monitoring events in 1995 and 1996.

To estimate the off-site concentrations of dust generated by these activities, measured on-site concentrations were used to estimate respirable dust emission rates. These emission rates and local meteorological data were used as input parameters for EPA-recommended air dispersion models to estimate off-site dust concentrations. The modeled concentrations of dust in ambient air offsite were combined with chemical concentrations detected in ash to evaluate potential human exposures via inhalation.

This approach is health-protective in that it assumes that all dust is ash-derived and that all of the chemicals detected in ash are transported to dust. As noted above, the dust measured during the daily cover demonstration project was not correlated with ash handling and use. Instead, the dust observed during the project was correlated with truck traffic on dusty roads and rock crushing activities at the adjacent quarry. However, the measured dust concentrations can be used as worst case estimates of the dust generated by ash handling and use.

On-Site Dust Concentrations. During the six day demonstration project during which air monitoring was performed, twelve day-long total suspended particulate samples were taken inside of the caterpillar tractor and the MSW compactor. The average TSP value was 0.278 mg/m^3. The average ratio of TSP to PM_{10} for samples taken inside of equipment was 0.38. Accordingly, the PM_{10} concentration for the landfill workers working inside the cabs of heavy equipment was derived as 0.105 mg/m^3.

One landfill worker, the spotter, worked outdoors throughout the entire work day. Five day-long samples of total suspended particulates were taken. The average TSP value was 0.558 mg/m^3. The average ratio of TSP to PM_{10} for samples outside was 0.24. Accordingly, the PM_{10} concentration for the landfill workers

working outside was derived as 0.134 mg/m^3.

To be health-protective, the respirable particulate (PM_{10}) concentration for the spotter was used for all on-site workers during daily operations. This concentration overestimates the exposures for workers who are working inside of earth moving equipment.

During the ash mining operation, one sample was taken for respirable dust on the window of the front end loader, but no samples were taken for total suspended particulates. Accordingly, the respirable dust value of 0.300 mg/m^3 was used for this potential receptor.

Samples collected during the 1996 demonstration project were used to derive the average outdoor TSP concentration. The average TSP concentration for all outdoor samples was higher than the average TSP concentration for all outdoor *downwind* samples. Of the total dataset of outdoor samples, those samples collected in upwind locations (e.g. at or near the adjacent quarry's rock crushing operations) were excluded. Thirty nine samples were taken outdoors in downwind areas where visitors might be exposed to on-site dust. The average TSP value was 0.268 mg/m^3. The average ratio of TSP to PM_{10} for samples outside was 0.24. Accordingly, the PM_{10} concentration for the on-site landfill visitors (landfill daily cover) or trespassers (landfill final cover) was derived as 0.064 mg/m^3.

Off-Site Dust Concentrations. PM_{10} emission rates were estimated from measured concentration data using a simple Box Model[14] and site-specific data for source length and mean wind speed (5.14 m/sec). The PM_{10} concentration in the box was assumed to be uniformly mixed by human activities on the landfill. Mixing height was assumed to be 2 m.

The SCREEN3 model (Version 95181)[15] was used to estimate offsite ambient PM10 concentrations for the various scenarios. SCREEN3 is a USEPA-preferred model and is recommended by USEPA for a screening-level air dispersion modeling . The SCREEN3 model determines 1-hour chemical concentrations. Eight-hour and annual average PM10 concentrations are calculated by multiplying factors of 0.7 and 0.08, respectively.

Wind data are site-specific with the stability of D and wind speed of 5.14 m/s. Source areas were modeled as ground-level area sources with site-specific areas. A receptor height of 1.0 m was assumed. Site locations were considered as rural areas, and they were modeled using the simple terrain approach because the terrain heights of nearby human receptors are lower than the emission sources.

RISK CHARACTERIZATION

Table 4 presents the results of the lead risk assessment for all receptors and scenarios for both the Landfill Daily Cover risk assessment (Waimanalo Gulch Sanitary Landfill) and the Landfill Final Cover risk assessment (Waipahu Landfill). In all cases, the 99th percentile blood lead concentration is less than the applicable blood lead health benchmark. In all cases, the majority of blood lead was associated with the assumed ingestion and dermal contact with ash. Only a small fraction was associated with inhalation of dust. For instance, for the Landfill Daily Cover risk assessment, inhalation of lead from ash-derived dust in air by on-site workers contributes 0.49 µg/dL, 7% of the total blood lead concentration. Inhalation of lead

from ash-derived dust in air by ash mining workers contributes 1.1 µg/dL, 15% of the total blood lead concentration. Inhalation of lead in ash-derived dust contributes less than 1% of the total blood lead concentration for the on-site adult visitor receptor. Inhalation of lead in ash-derived dust contributes less than 0.1% of the total blood lead concentration for the on-site child visitor receptor.

The same is true for the Landfill Final Cover risk assessment. Inhalation of lead from ash-derived dust in air contributes 0.20 µg/dL, 4% of the total blood lead concentration for construction workers. For the trespasser closure scenarios (assuming no stockpile, stockpile present, and uncovered ash), inhalation of lead in ash-derived dust contributes less than 1% of the total blood lead concentration for each receptor.

For other receptors and scenarios, such as the West Loch recreator (Closure-Stockpile, Closure-Uncovered, and Post-Closure scenarios), exposures to lead in background air, food, and water contribute essentially all of the 99th percentile blood lead concentrations. Surface water, sediment, and fish consumption exposures are associated with less than 1% of the total blood lead concentration for each receptor.

Table 5 presents the results of the noncarcinogenic risk assessment for all receptors and scenarios for both the Landfill Daily Cover risk assessment (Waimanalo Gulch Sanitary Landfill) and the Landfill Final Cover risk assessment (Waipahu Landfill). In all cases, the hazard indices are less than 1.0. These results indicate that proposed use of ash for daily cover at the landfill poses no unacceptable incremental increase in noncarcinogenic health risks.

Estimated Lifetime Cancer Risks (ELCRs) are also shown in Table 5. For all receptors and scenarios, the estimated cancer risk is within or below U.S. EPA's acceptable risk range of 10^{-4} to 10^{-6} and OSHA's criteria of 1×10^{-3} for setting occupational standards. Note that inhalation risks for all receptors were calculated based on the assumption that 100% of dust is ash-derived (*i.e.*, 100% of metals concentrations detected in ash were assumed to be present in dust), and that worker risks were estimated assuming that exposure occurs without regard to personal protective equipment and personal hygiene practices required under the applicable OSHA standards for arsenic, cadmium, and lead.

SUMMARY AND CONCLUSIONS

Human health risk assessments were performed for two proposed beneficial uses of H-Power combined ash: Landfill Daily Cover (Waimanalo Gulch Sanitary Landfill) and Landfill Final Cover (Waipahu Landfill). In all cases, with all receptors and ash use scenarios, estimated blood lead concentrations were less than 25 μg/dL for adult male workers and 10 μg/dL for nonworkers assumed to be young children or female adults of child-bearing age. Estimated hazard indices were all less than 1.0, and estimated excess lifetime cancer risks were within or below U.S. EPA's acceptable risk range of 10^{-4} to 10^{-6} and OSHA's criteria of 1×10^{-3} for setting occupational standards.

Ambient and personal monitoring was performed during a demonstration project of landfill daily cover. Although no metals were detected in total or respirable dust and total dust was not found to be correlated with ash handling and use, measured dust concentrations were assumed to represent worst case estimates of ash-generated dust levels. The risk assessment assumed that dust was totally ash-derived, and ash-derived metal concentrations were derived from the total metals content of H-Power combined ash. Even with this very health-protective assumption, the risk assessment results were found to be dominated by the assumptions that potential receptors would directly ingest and dermally contact H-Power combined ash.

While such assumptions are commonly made by risk assessors, it should be noted that construction workers or landfill workers must adhere to strict requirements concerning personal hygiene practices and the use of personal protective equipment required under the applicable OSHA standards for arsenic, cadmium, and lead. Thus, assuming that workers will violate Federal law is a very health-protective approach to human health risk assessment.

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TABLE 1
TOTAL DUST CONCENTRATIONS

OSHA STATIONS	Day 1 7/10/96 (mg/m3)	Day 2 7/11/96 (mg/m3)	Day 3 7/12/96 (mg/m3)	Day 4 7/13/96 (mg/m3)	Day 5 7/14/96 (mg/m3)	Day 6 7/15/96 (mg/m3)
OSHA U	0.73	1.0	0.43	1.3	0.36	0.21
OSHA D	0.31	0.54	0.32	0.45	0.94	0.20
CAT	0.11	0.22	0.19	0.17	0.25	0.60
COMP	<0.02	0.41	0.27	0.62	0.20	0.28
SPOT	0.48	0.59*	0.07	1.4	0.63	0.21
AMBIENT STATIONS						
U S1	0.2	0.42	0.36	0.1	<0.08	<0.1
U S2	0.65	0.44	0.76	0.27	0.05	0.09
U S3		0.4	<0.2	<0.1		
U S4	<0.02	<0.02	0.06	<0.02	<0.02	<0.02
D1 S1	<0.09		0.3		<0.07	
D1 S2	0.62		0.3		0.12	
D1 S3						
D1 S4			<0.02		<0.02	
D1A S1		0.34		0.33		0.2
DIA S2		0.22		0.39		
DIA S3		<0.2		<0.2		
DIA S4		<0.02		<0.02		0.03
D2 S1	<0.09		<0.07		<0.07	
D2 S2	0.23		0.30		0.17	
D2 S3			<0.2			
D2 S4	<0.02				<0.02	
D2A S1		0.42		<0.02		<0.1
D2A S2		<0.03		0.16		<0.03
D2A S3		<0.2		<0.2		
D2A S4		<0.02		<0.02		<0.02
ASH DUMP		0.83		0.44		0.05
ASH MINING						
ASH MINE DUMP			<0.08			
ASH MINE LOADER						

NOTES:

*Cassette found on the ground and reconnected to sampling apparatus.

TABLE 2
RESPIRABLE DUST CONCENTRATIONS

OSHA STATIONS	Day 1 7/10/96 (mg/m3)	Day 2 7/11/96 (mg/m3)	Day 3 7/12/96 (mg/m3)	Day 4 7/13/96 (mg/m3)	Day 5 7/14/96 (mg/m3)	Day 6 7/15/96 (mg/m3)
OSHA U	0.19	0.23	0.09	0.25	0.03	0.08
OSHA D	0.05	0.27*	0.11	0.09	0.08	0.09
CAT	0.03	0.07	<0.02	0.09	0.05*	0.24
COMP	0.04	0.14	0.13	0.25	0.13	0.07
SPOT	0.09	0.18	0.17*	0.15	0.18	0.06
AMBIENT STATIONS						
U S1	0.4	<0.08	<0.09	<0.09		<0.2
U S2	0.03	0.03	0.05	0.1	<0.04	
U S3		<0.2	<0.3	0.3		
U S4	<0.02	<0.02	<0.02	0.6	<0.02	<0.02
D1 S1	<0.1		<0.08		<0.08	
D1 S2	0.1		0.04		0.05	
D1 S3			<0.2			
D1 S4	<0.02		<0.02		<0.02	
D1A S1		<0.08		0.84		<0.2
DIA S2		0.05		0.07		
DIA S3		<0.2		<0.2		
DIA S4		<0.02		<0.02		<0.02
D2 S1	<0.1		0.2		<0.08	
D2 S2	<0.03		<0.04		0.09	
D2 S3			<0.2			
D2 S4	<0.02		<0.02		<0.02	
D2A S1		<0.07		<0.08		
D2A S2		<0.04		0.1		
D2A S3		<0.2		<0.2		
D2A S4		<0.02		<0.02		<0.02
ASH DUMPING		0.04		0.02		<0.03
ASH MINING						
ASH MINE DUMP			<0.09			
ASH MINE LOADER			0.3			

NOTES:

*Laboratory report indicated sample was contaminated with tap water; results may be biased high.

TABLE 3
DATA SUMMARY FOR H-POWER COMBINED ASH

Chemical	Concentration in Ash (Dry Weight, mg/kg)[1,2]	Concentration in TCLP Leachate (mg/L)[2,3]
Arsenic	49	0.67
Barium	410	1.6
Cadmium	29	0.31
Chromium	69	0.064
Lead	2500	1.0
Mercury	11	0.0045
Nickel	75	not analyzed
Selenium	0.91	0.19
Silver	7.1	0.088
TCDD-Toxic Equivalents[4]	0.00043	not analyzed

[1] Combined ash samples with metal pieces removed, samples collected during 3/20/95-12/18/95.
[2]Upper 95% confidence interval of the mean concentration using H statistic per U.S. EPA guidance assuming lognormal distribution.
[3]Combined ash samples with metal pieces removed, samples collected from 12/89-8/95.
[4]Mean of two samples in which total congener profile was measured.

TABLE 4
ESTIMATED BLOOD LEAD CONCENTRATIONS

LANDFILL DAILY COVER

Receptor	95th %ile (ug/dl)	99th %ile (ug/dl)
On-Site Worker pushing/compacting MSW/Daily Cover	5.3	6.7
On-Site Worker - ash mining	5.8	7.3
On-Site Visitor - young child	2.7	3.4
On-Site Visitor - female of childbearing age	1.4	1.8
Off-Site Resident - young child	1.5	1.9

LANDFILL FINAL COVER

Receptor	95th %ile (ug/dl)	99th %ile (ug/dl)
On-Site Construction Worker	4.0	5.0
On-Site Trespasser (young child)		
Closure No Stockpile	2.1	2.7
Closure with Stockpile	2.7	3.4
Closure Uncovered	2.7	3.4
Off-Site Resident (young child)		
Closure No Stockpile	1.5	1.9
Closure with Stockpile	1.5	1.9
Closure Uncovered	1.5	1.9
Post Closure	1.5	1.9
Recreator (fishing/swimming)		
Closure with Stockpile	1.5	1.9
Closure Uncovered	1.5	1.9
Post Closure	1.5	1.9
Recreator (child dirt biking)		3.4
Post Closure	2.7	

TABLE 5
ESTIMATED NONCARCINOGENIC AND CARCINOGENIC HEALTH RISKS

LANDFILL DAILY COVER

Receptor	Hazard Index	Cancer Risk
On-Site Worker pushing/compacting MSW/Daily Cover	0.4	3×10^{-5}
On-Site Worker - ash mining	0.6	5×10^{-5}
On-Site Visitor - young child	0.2	4×10^{-6}
On-Site Visitor - female of childbearing age	0.05	4×10^{-6}
Off-Site Resident - young child	0.001	2×10^{-8}

LANDFILL FINAL COVER

Receptor	Hazard Index	Cancer Risk
On-Site Construction Worker		
Closure No Stockpile	0.2	2×10^{-6}
Closure with Stockpile	0.2	2×10^{-6}
Closure Uncovered	0.2	2×10^{-6}
On-Site Trespasser (young child)		
Closure No Stockpile	0.08	9×10^{-7}
Closure with Stockpile	0.3	1×10^{-6}
Closure Uncovered	0.3	2×10^{-6}
Off-Site Resident (young child)		
Closure No Stockpile	0.001	2×10^{-8}
Closure with Stockpile	0.008	2×10^{-8}
Closure Uncovered	0.001	2×10^{-8}
Post Closure	0.0008	2×10^{-8}
Recreator (fishing/swimming)		
Closure with Stockpile	0.001	7×10^{-8}
Closure Uncovered	0.004	2×10^{-7}
Post Closure	0.07	9×10^{-7}
Recreator (child dirt biking)		
Post Closure	0.2	1×10^{-6}