ACEHWCF – A Comprehensive Risk Assessment Model For Hazardous Waste Combustion Facilities

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ABSTRACT

A comprehensive risk assessment model has been developed for evaluating potential health risks from air toxics emitted by hazardous waste combustion facilities. The model, known as ACEHWCF, fully meets the requirements of the U.S. EPA risk assessment guidelines. It is interfaced with regulatory dispersion models, such as ISCST3 and the upcoming ISC-PRIME and AERMOD models. The model has been applied to two test cases , a mercury exposure scenario and an actual hazardous waste combustion facility. Modeling results closely agree with those obtained by EPA Region 6, and they affirm the model validity and accuracy. The ACEHWCF model is an efficient tool for preparing risk assessments for a single facility or multiple facilities in a cumulative study, and the model usage should expedite their review and approval by regulatory agencies.

INTRODUCTION

As part of the RCRA permitting process, site-specific risk assessments may be required for hazardous waste combustion facilities to protect human health and the environment. U.S. Environmental Protection Agency (EPA) has developed in 1998 a draft Human Health Risk Assessment Protocol (HHRAP) for such facilities (US EPA, 1998). This protocol is intended to: (1) serve as national guidance to consolidate information in other risk assessment guidance and methodology documents previously prepared by U.S. EPA and state environmental agencies; and, (2) address issues that have been identified while conducting risk assessments for existing hazardous waste combustors. The EPA protocol has undergone extensive reviews, both internal and external with the last peer review meeting held in May 2000.

This paper describes the development of a comprehensive health risk assessment model that meets the requirements of the EPA Protocol. The model is given the acronym ACEHWCF (**A**ssessment of **C**hemical **E**xposure for **H**azardous ***W***aste **C**ombustion **F**acilities) and incorporates the HHRAP algorithms and recommendations. The ACEHWCF model is designed for a multi-source, multi-pollutant and multipathway risk assessment. It is capable of evaluating incremental health risks from a single facility or cumulative risks from several facilities in a cumulative or regional analysis. Model development and results of a recent application of the ACEHWCF model are described below.

MODEL DEVELOPMENT

The health risk assessment of toxic pollutants emitted from a facility typically involves the following steps:

1) identify compounds of potential concern (COPC) and their emissions,
2) calculate pollutant concentrations and deposition in ambient air through dispersion modeling,
3) evaluate pollutant concentrations and deposition in other media such as soil, drinking water and food,
4) estimate exposure doses, and
5) characterize health risks.

Methodologies implemented in the ACEHWCF model for each of these steps are described below. Details are presented in a user's guide of the ACEHWCF model[2].

Identification of Toxic Pollutants

Hazardous waste combustion generally results in combustion by-products being emitted from a stack. In addition to stack emissions, other types of emissions include (1) process upsets, (2) general RCRA fugitive emissions, (3) cement kiln dust (CKD) fugitive emissions, and (4) accidental releases. Accidental releases are normally not considered in health risk assessments due to their non-routine nature. For existing facilities, stack emission rates are either long-term average emission rates adjusted for upsets, or (2) reasonable maximum emission rates measured during trial burn conditions. For new or not yet operational facilities, surrogate emissions from a similar operating facility may be used but, following the facility construction, an additional risk assessment is required using emission rates collected during actual trial burn conditions. COPCs are identified from the trial burn data based on their potential to pose increased risk or hazard via one or more of the direct or indirect exposure pathways. They are typically identified in seven different general categories: polychlorinated dibenzo(p)dioxins (PCDD), polychlorinated dibenzofurans (PCDF), polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), nitroaromatics, phthalates, other organics and metals.

Air toxics and associated health effect data recommended in the US EPA protocol are contained in an input file to the ACEHWCF model (the PCHEM.DAT file). This database contains over 200 carcinogens and noncancer pollutants. Unit risk factors (URF) for computing cancer risk through inhalation and oral cancer slope factors (Oral CSF) for estimating risk from non-inhalation pathways are specified for carcinogens. Reference concentration (RfC) and reference doses (RfD) are required for pollutants with noncancer chronic exposure effects. Acute inhalation exposure criteria (AIEC) are specified for

noncancer acute pollutants. The model can compute both total hazard indices that are summed across pollutants and exposure routes, and hazard indices segregated by affected target organs. Affected toxicological endpoints are specified through indicator flags. Toxicological targets considered in the ACEHWCF model include cardiovascular system, central nervous system, immune system, kidney, liver, reproductive system, respiratory system, eye and skin.

Calculation of Pollutant Concentrations in Air

Since potential health effects from a combustion facility are known to be localized, Gaussian-based dispersion models are frequently used to predict pollutant concentrations and deposition (wet and dry) in ambient air. The ACEHWCF model is capable of interfacing with several regulatory dispersion models, e.g. ISCST3 and the upcoming ISC-PRIME and AERMOD models. Three modeling runs are required to accommodate the different phases of COPC emissions: vapor, particle and particle-bound. In general, most metals and organic COPCs with very low volatility (vapor fraction Fv less than 0.05) occur only in the particle phase. Organic COPCs can occur as either only vapor phase (Fv=1.0) or with a portion of the vapor condensed onto the surface of particulate (e.g. particle-bound). COPCs released only as particulate are modeled with different mass fractions allocated to each particle size than the mass fractions for the organics released in both the vapor and particle-bound phases. Normally, five years of appropriate meteorological data are used in the modeling.

The ACEHWCF model assumes that all emission sources from the facility are modeled by a guideline dispersion model with appropriate meteorological data, stack parameters and receptor locations. Unit emission rates (1 g / s) are used for all sources in the dispersion modeling run and a AMI-modified version of the dispersion model (e.g. ISCST3, ISC-PRIME or AERMOD) is used to compute for each emitted COPC the peak 1-hour concentrations and annual-averaged concentrations and deposition for each individual source and all sources combined at each receptor from actual input emission rates. The model also computes partial contributions from each source to these peak 1-hour and annual concentrations. Peak 1-hour concentrations are used in quantifying non-cancer acute health effects, and annual-averaged concentrations and deposition rates in carcinogenic and non-cancer chronic health effects. The approach of calculating the required 1-hour and annual concentrations and deposition directly in the AMI-modified dispersion model has been successfully used by AMI in our other air toxics health risk assessment model ACE2588[3]. This approach does not require a big partial concentration file and allows an accurate analysis of the contributions from each individual emission source.

Calculation of Pollutant Concentrations in Other Media

For pollutants with non-inhalation exposure (i.e., multipathway pollutants), concentrations in other media are required for risk assessments. For these pollutants, the ACEHWCF model uses the algorithms recommended in the U.S. EPA Protocol to compute pollutant deposition and concentrations in soil, drinking water, produce (root and non-root crops), farm animals (beef, milk, pork, chicken, egg) and fish. Chemical-specific fate and transport parameters (such as vapor phase fraction Fv) and site-specific factors (such as water surface area and average annual rainfall) are considered in the calculations. Chemical –specific parameters are taken from Appendix A of the U.S. EPA Protocol and stored in the PCHEM.DAT file. Site-specific factors are stored in the PSITE.DAT input file. To accommodate a variety of local settings, food sources can be located on-site or off-site. For example, produce can be grown either at home or at off-site commercial locations. Facility impacts on watershed areas and water bodies (for sources of drinking water or fishing) can be represented by dispersion model predictions at a single receptor or predictions averaged over several receptors for large watershed areas and water bodies.

Calculation of Exposure Doses

The ACEHWCF model utilizes pollutant concentrations in air and other media to evaluate exposure to humans. Exposure is evaluated by calculating the daily intakes and the lifetime average daily doses from all applicable pathways. In addition to inhalation doses, multipathway pollutants require the calculations of doses from other pathways (i.e., dermal absorption, soil ingestion, drinking water ingestion, food ingestion through produce, farm animal products and fish). As recommended by the U.S. EPA Protocol, potential health risks are calculated for receptor-specific exposure scenarios that include resident (adult and child), farmer (adult and child) and fisher (adult and child). Exposure duration varies from 6 years for all children to 30 years for the adult resident and fisher. The adult farmer is exposed for 40 years. The user has the flexibility of specifying applicable exposure pathways for each modeled exposure scenario.

Calculation of Health Risks

Potential health risks are quantified with the calculated exposure doses. Both carcinogenic and non-carcinogenic health effects are predicted by the ACEHWCF model. Special analyses are required for dioxins and lead as shown below.

Cancer Risk and Excess Burden

The ACEHWCF model computes the total excess cancer risk from both inhalation and non-inhalation pathways at each receptor location. The inhalation risk for each pollutant at a receptor location is calculated by multiplying the pollutant concentration in ambient air by its unit risk factor. For a multipathway pollutant, the non-inhalation risk is

calculated as the product of its potency slope and the average daily dose of the substance, which is the sum of all non-inhalation doses. The estimated risks for individual substances are added together to provide the total excess cancer risk at each receptor location.

For risk management purposes, the ACEHWCF model identifies the maximum individual excess cancer risk, the receptor where this maximum is predicted to occur, and receptors with risks predicted to equal or exceed a user-specified significant risk level (e.g., 10 in a million). For this peak receptor, the model can produce tables showing risk contributions by source and by pollutant and the lifetime average daily doses. These tables can be generated for any other receptor requested by the user.

If population data is given, excess burden at each receptor is computed by multiplying the predicted risk by the receptor population. Excess burden is computed only for receptors with risks predicted to equal or exceed a user-specified risk level of the impact zone (e.g., 1 in a million). The total excess burden is then computed as the sum of excess burdens at all receptor locations.

Noncancer Acute Health Effects

If the facility emits pollutants with known acute health effects (e.g., chlorine and ammonia), then the ACEHWCF model computes a total hazard index for respiratory irritation at each receptor. The hazard index for each pollutant is computed as the ratio of the total pollutant concentration (concentration from facility emissions plus ambient background if given) over the chemical-specific acceptable inhalation exposure criteria (AIEC). The total hazard index is then computed as the sum of hazard indices of all relevant pollutants. The model can compute both total hazard indices that are summed by pollutants, and hazard indices segregated by affected target organs. Affected toxicological endpoints are specified through indicator flags in the PCHEM.DAT file. Toxicological targets considered in the ACEHWCF model include cardiovascular system, central nervous system, immune system, kidney, liver, reproductive system, respiratory system, eye and skin.

Acute health effects are significant if the total hazard index at a receptor is equal or greater than 1. For risk management purposes, the ACEHWCF model identifies the maximum predicted hazard index, the receptor where this maximum occurs, and all receptors with significant hazard indices. For the peak receptor and other user-specified receptors, the model can produce tables showing contributions to the calculated hazard indices from each source and each pollutant.

Noncancer Chronic Health Effects

Similar to the evaluation of acute health effects, hazard indices are used to quantify chronic health effects. Inhalation hazard quotients are computed by first converting COPC

air concentrations to average daily doses and then dividing them by the reference doses (RfD). For multipathway pollutants, the ratio of the sum of non-inhalation doses over the RfD is added to the hazard index computed from inhalation exposure. The model can compute both total hazard indices that are summed by pollutants and exposure pathways, and hazard indices segregated by affected target organs. Affected toxicological endpoints are specified through indicator flags in the PCHEM.DAT file. Toxicological targets considered in the ACEHWCF model include cardiovascular system, central nervous system, immune system, kidney, liver, reproductive system, respiratory system, eye and skin.

If the total hazard index for any toxicological endpoint is equal to or greater than 0.25, then potential chronic health effects are considered to be significant. The ACEHWCF model produces tables showing the maximum hazard index, the peak receptor, other receptors with significant health effects, and contributions by source and by pollutant at the peak receptor and other receptors specified by the user.

Dioxin and Lead Exposure Assessment

For quantifying the health effects of dioxins in mother's milk, the ACEHWCF model computes the average daily dose to the exposed infant. This daily dose can be compared to the average infant intake target level recommended by regulatory agencies. U.S. EPA Region 6 has recommended calculating infant daily dose for only 2,3,7,8-TCDD Toxicity Equivalent Quotient (TEQ) and comparing it against a target level of 60 pg/kg-day of 2,3,7,8-TCDD TEQ[4].

For lead, the ACEHWCF model computes lead concentrations in air and soil. These concentrations can be compared against target levels recommended by regulatory agencies. For example, U.S. EPA Region 6 recommends target levels of 0.2 ug/m3 in air and 100 mg/kg in soil.

Computer Implementation

The ACEHWCF computer code is written in Fortran 95 and an efficient memory management scheme is implemented so that the model can operate on personal computers. All chemical-specific and pathway-specific data are stored in input files that can be modified to add new substances or update site-specific data as required by regulatory agencies. A user-friendly, menu-driven preprocessor (PreACE) is also available to facilitate the preparation of the project-specific input file. Significant modeling results are summarized in a one-page output. The model also creates a separate output file in a format ready for input to graphics-generating programs. ACEHWCF produces a comprehensive printed output that clearly shows all modeling inputs and model predictions. This distinct feature of the model expedites the review of the risk assessments and their acceptance by

regulatory agencies.

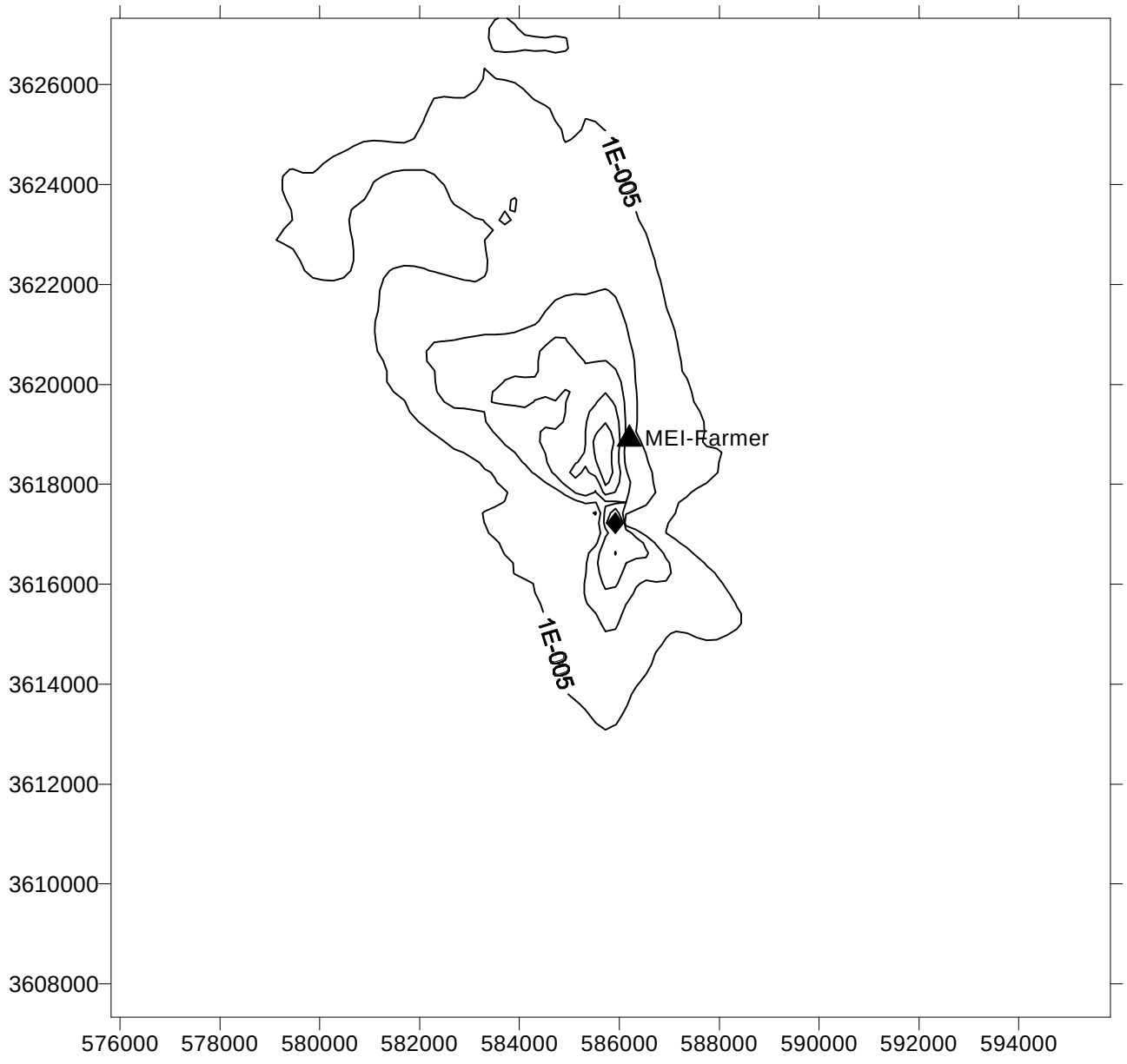
MODEL VALIDATION AND APPLICATION

As a verification test, the ACEHWCF model has been applied to calculate the non-cancer chronic hazard index for an adult fisher consuming fish exposed to mercury. This is the same test from U.S. EPA Region 6 that shows how to apply the HHRAP algorithms[5]. The ACEHWCF output is available from the AMI web site[6]. A maximum chronic hazard index of 15.719 is calculated by ACEHWCF and agrees with the EPA result.

The ACEHWCF model has also been used to evaluate potential health risks from a hazardous waste combustion facility proposed by Angus Chemical in Sterlington, Louisiana. Potential health risks from this facility has recently been evaluated by U.S. EPA Region 6[7]. This model simulation involved the use of the ISCST3 model and a 5-year sequential meteorological data set. Stack emissions from the boiler are modeled as a point source and fugitive emissions are represented by three volume sources. The facility emits a total of 223 pollutants. Three separate ISCST3 modeling runs were performed (vapor phase for all four sources, particle and particle-bound phases for the boiler only) for over 5200 gridded receptors.

A contour map of cancer risk predicted by the ACEHWCF model is shown in Figure 1. ACEHWCF predicted a maximum cancer risk of 5.16E-5 for an adult farmer. Ingestion of farm animal products (e.g., cow milk) accounts for 95% of this maximum risk, primarily from indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene. The biotransfer factors for animal products for these PAH compounds are not well known and, due to their large uncertainties, their risk contributions have been neglected as recommended by the EPA Region 6. As a result, the maximum cancer risk is below the significance level of 10 in a million. Maximum noncancer acute and exposure hazard indices and other health effects (e.g. lead and TCDD exposure) are below their respective significance levels. All these modeling results closely agree with those obtained by EPA Region 6, and affirm the validity and accuracy of the ACEHWCF model.

Figure 1 - Risk Contours Predicted by ACEHWCF



SUMMARY

A comprehensive risk assessment model has been developed for evaluating potential health risks from air toxics emitted by hazardous waste combustion facilities. The model, known as ACEHWCF, fully meets the requirements of the U.S. EPA Protocol.
The model has been applied to two test cases , a mercury exposure scenario and an actual hazardous waste combustion facility. Modeling results closely agree with those obtained by EPA Region 6, and they affirm the validity and accuracy of the ACEHWCF model. The model is an efficient tool for preparing risk assessments for a single facility or several facilities in a cumulative study. The model usage should expedite their review and approval by regulatory agencies.

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KEYWORDS

Hazardous waste combustion
Health risk assessment
Dispersion modeling
US EPA risk assessment protocol