Risk Assessment Document for Coke Oven MACT Residual Risk

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Executive Summary

Under the Clean Air Act (CAA), the U.S. Environmental Protection Agency (EPA) is required to develop and implement maximum achievable control technology (MACT) standards for source categories that emit any of the listed hazardous air pollutants (HAPs). Following implementation of the MACT standards, EPA is required to assess the human health and environmental risks that may remain as a result of the continued, routine emissions of HAPs. This latter analysis is part of the Residual Risk program which was initially describe in the EPA's 1999 *Residual Risk Report to Congress* (U.S. EPA, 1999c).

The residual risk analysis described in this report addresses four coke plants subject to the 1993 coke oven MACT standards (40 CFR Part 63 Subpart L) and estimates potential risks due to HAPs emissions from facilities involved in coking operations. This analysis assessed the routine emissions from charging operations, door, lid and offtake leaks (MACT I); pushing and quenching operations; combustion stacks (MACT II); and the By-product recovery plants at each facility. This analysis included screening level risk assessments which were intended to narrow the focus of further work to only those components that may drive any potential health concerns. These screens included human health screens that focused on inhalation and non-inhalation exposures and an ecological screen.

Results from the inhalation screen showed that all four facilities had estimated, lifetime, cancer risks greater than 1 in a million, whereas, only two of the facilities had non-cancer hazard quotients that exceeded the scoping criteria. The majority of the cancer risk was driven by coke oven emissions and benzene while the non-cancer hazards were driven by benzene and arsenic. In the ingestion screening assessment, two exposure scenarios were considered; central tendency and high-end exposure. The ingestion screening assessment showed that the estimated, ingestion cancer risk (using the high-end exposure factors) was close to an order of magnitude less than the the estimated cancer risk resulting from the screening inhalation exposures, and that the highest facility level hazard index did not exceed 0.001. The ingestion risks and hazards were driven by PAHs. These screening analyses established that only impacts from inhalation exposures were the greatest human health concern from coke plants emissions.

We also conducted a screening-level assessment to determine if there were any significant ecological effects that warranted a more refined level of analysis. The assessment endpoints were the structure and function of generic aquatic and terrestrial populations and communities that might be exposed to HAP emissions from the four coke oven facilities. It was assumed that these ecological receptors were representative of sensitive individuals, populations, and communities that may be present near any of the four coke oven facilities. The results showed that for all HAPs, media, ecological receptors and exposure pathways screened, none of the four coke facilities had HQs greater than 1, indicating that it is not likely that any HAPs emitted from coke ovens pose an ecological risk to ecosystems near those facilities. It is also not likely that any threatened and endangered species, if they existed around these facilities, would be adversely affected by these emissions because they are not likely to be any more sensitive to the effects of these HAPs than the species whose screening values were used.

The results of all of these screening assessments determined that the scope of the more refined risk analysis would include only an assessment of human health, inhalation cancer risk and hazard. Results from the more refined level of analysis showed that the emissions from these four facilities are not considered to cause a potential concern for adverse noncancer health impacts but do pose potential cancer risks to the individual most exposed living within 50 km of these facilities. This individual is predicted to have a maximum lifetime excess cancer risk exceeding 1 in a million ($> 1x10^{-6}$) with the highest risk at the AK Steel–Ashland facility, exceeding 100 in a million ($> 1x10^{-4}$). Based on this residual risk assessment, EPA must determine whether additional standards are necessary to adequately protect human health with an ample margin of safety. This report describes the details of this residual risk assessment.

1.0 Context

1.1 Background

The Residual Risk Program described in the CAA, requires EPA to evaluate whether the continued emissions of HAPs from source categories regulated under the MACT program protect public health and are protective of the environment. If not, this statute directs EPA to set additional standards if it is determined that the level of emissions established by the MACT standards do "not reduce the lifetime excess cancer risks to the individual most exposed .....to less than one in one million..." Any standards set under this section are to ensure that the public health is protected to a level which provides an "ample margin of safety". In addition, EPA is to protect the environment against adverse effects. Elements of the residual risk program are described in the 1999 *Residual Risk Report to Congress* (U.S. EPA, 1999c).

This 1999 Report provides the general framework for conducting risk assessments used to support decisions to be made. Cancer and noncancer health impacts generally cannot be directly isolated and measured with respect to environmental exposures. Even if it were possible to do so, we would not be able to assess the impacts of future or alternative control strategies. As a result, risk assessment is used as a tool to predict potential health risks for many Agency programs. In risk assessments, there is essentially a continuum of possible levels of analysis, from the most basic screening approach to the more refined, detailed assessment. The results presented in this Coke Oven risk assessment include screening level assessments for human health inhalation and non-inhalation, and environmental exposures. The purpose of these screens is to narrow the scope of a more refined analyses by limiting the number HAPs, exposure routes, emission points, or facilities which might require additional data gathering before further analysis. The screening assessment is intended to be health protective so that risks are not likely to be underestimated in order to ensure that the more refined analysis is performed on those factors that are the risk drivers.

The term ample margin of safety was not specifically defined in the CAA. However, the Residual Risk section of the CAA expressly preserves the interpretation of "ample margin of safety" used in the pre-1990 version of the CAA. That interpretation is reflected in the 1989 rulemaking promulgating National Emissions Standards for Hazardous Air Pollutants for sources of benzene (the Benzene NESHAP ((54 FR 38044)). In that rule, EPA explained that, "in protecting public health with an ample margin of safety ......, (we) strive to provide maximum feasible protection against risks to health from hazardous air pollutants by (1) protecting the greatest number of persons possible to an individual lifetime risk level no higher than approximately 1 in a million and (2) limiting to no higher than approximately 1 in 10 thousand the estimated risk that a person living near a plant would have if they were exposed to the maximum pollutant concentrations for 70 years."

In the approach used in the Benzene NESHAP, the first step of the two step ample margin of safety framework is the determination of acceptability, (i.e., the level of risks which can be considered "acceptable" based on health considerations only. Costs, technical feasibility and other relevant factors are not considered at this stage). The determination of what represents an acceptable risk level is to be made in the context of "the world in which we live", that is, recognizing that our world is not risk-free. In the Benzene NESHAP, EPA determined that the cancer risk to the individual with maximum exposure to emissions from the sources in question could not be considered acceptable unless that risk was below 1 in ten thousand ($1x10^{-4}$). This determination established a "presumptive" level of $1x10^{-4}$ cancer risk, thereby providing a benchmark for judging the acceptability of maximum individual risk for future risk-based emission standards, but not constituting a rigid line for making those judgments. When characterizing the risk levels estimated in this, current, risk assessment, we will use the 1 in a million risk and 100 in a million risk decision points as determined at each facility as the starting point for making the required ample margin of safety decisions.

We have adapted a similar framework for making decisions about our level of concern for noncancer effects. In considering total hazard exposure, a hazard index limit of 1 for each facility should ordinarilly represents the safe or acceptable level. A hazard index is derived by summing all of the relevant hazard quotients which are calculated as the ratio of the exposure concentration to the noncancer benchmark of each HAP. In making the ample margin of safety determination, technical feasibility and costs would be considered along with health information. This level may be lower or equal to the acceptable level but can never be higher.

EPA developed two distinct MACT standards for the Coke Oven source category. The MACT I standards (National Emission Standards for Hazardous Air Pollutants for Source Categories and for Coke Oven Batteries (40 CFR Part 63 Subpart L)), promulgated in 1993, address emissions from charging and leaks from doors, lids, and offtakes. The MACT II standards (National Emission Standards for Hazardous Air Pollutants for Coke Ovens: Pushing, Quenching, Battery Stack (66FR 35326)) were promulgated on April 14, 2003. This rule addresses the emissions from pushing, quenching, and combustion stacks.

For the 1993 MACT I rule, EPA established two "tracks" of technology based standards which specify different compliance timetables. These two tracks are generally referred to as the MACT track and the LAER (lowest achievable emissions rate) track. The LAER track batteries are those sources that voluntarily agreed to meet more stringent technology-based standards beginning in 1993. The LAER standards tighten over time with the final LAER technology standards becoming effective in 2010. The LAER track batteries are not required to meet residual risk standards until 2020. Those batteries (there are 5 batteries) that chose the MACT track compliance level are the subject of this risk assessment.

In addition to the battery operations that are covered by the MACT I, this risk assessment included emission sources regulated under MACT II standards and also includes risk associated with emissions from coke oven By-product plants regulated under the National Emission Standard for Hazardous Air Pollutants (NESHAP) for Benzene (40 CFR Part 61 Subpart L). Although this residual risk determination will only consider emissions from the MACT I sources, this assessment looked more broadly to include other emission points that are part of the coking process but subject to different residual risk analysis timing. This is consistent with the 1999 *Residual Risk Report to Congress* which stated that EPA would evaluate risk at the facility level whenever the data are available to do so in order to have some broader frame of reference for the specific risk standard decision being made.

The risk assessment was designed to address the questions posed by the Residual Risk section of the CAA. The initial question is to determine if at least one facility in the source category has cancer risk levels that exceed 1 in a million when risk to the individual most exposed is considered. If the answer to the initial question shows that cancer risk does exceed 1 in a million, then this assessment should identify the maximum risk to people living around each facility and determine if an ample margin of safety exists.

2.0 Risk Assessment Approach

This section of the report describes the various analyses that were done for this risk assessment on Coke Ovens. Figure 2-1 provides a graphic description of the approach taken. The Management Goals for this assessment are described briefly in Section 1. This document does not attempt to characterize the risks estimated in this analysis or to describe any risk management options that may be identified as a result. It confines itself to the problem formulation and risk assessment steps. The text in the main body of this report, (i.e., Sections 2 and 3) include descriptions of the health effects, a characterization of the source category, the methods used for modeling and exposure assessment, the descriptors of risk, the methods and scope of the uncertainty and variability analysis, and the summary tables of the risk results from the various aspects of the assessment. The Appendices, (i.e., A through I) provide more detailed, technical back-up materials, such as emissions estimation methods and data, model descriptions, inputs that more fully describe the technical approach, and risk results. This assessment was conducted iteratively and included separate inhalation, ingestion, and ecological screening assessments, the purpose of which was to narrow the scope of the more refined level assessment that would be used to answer various, required risk questions.

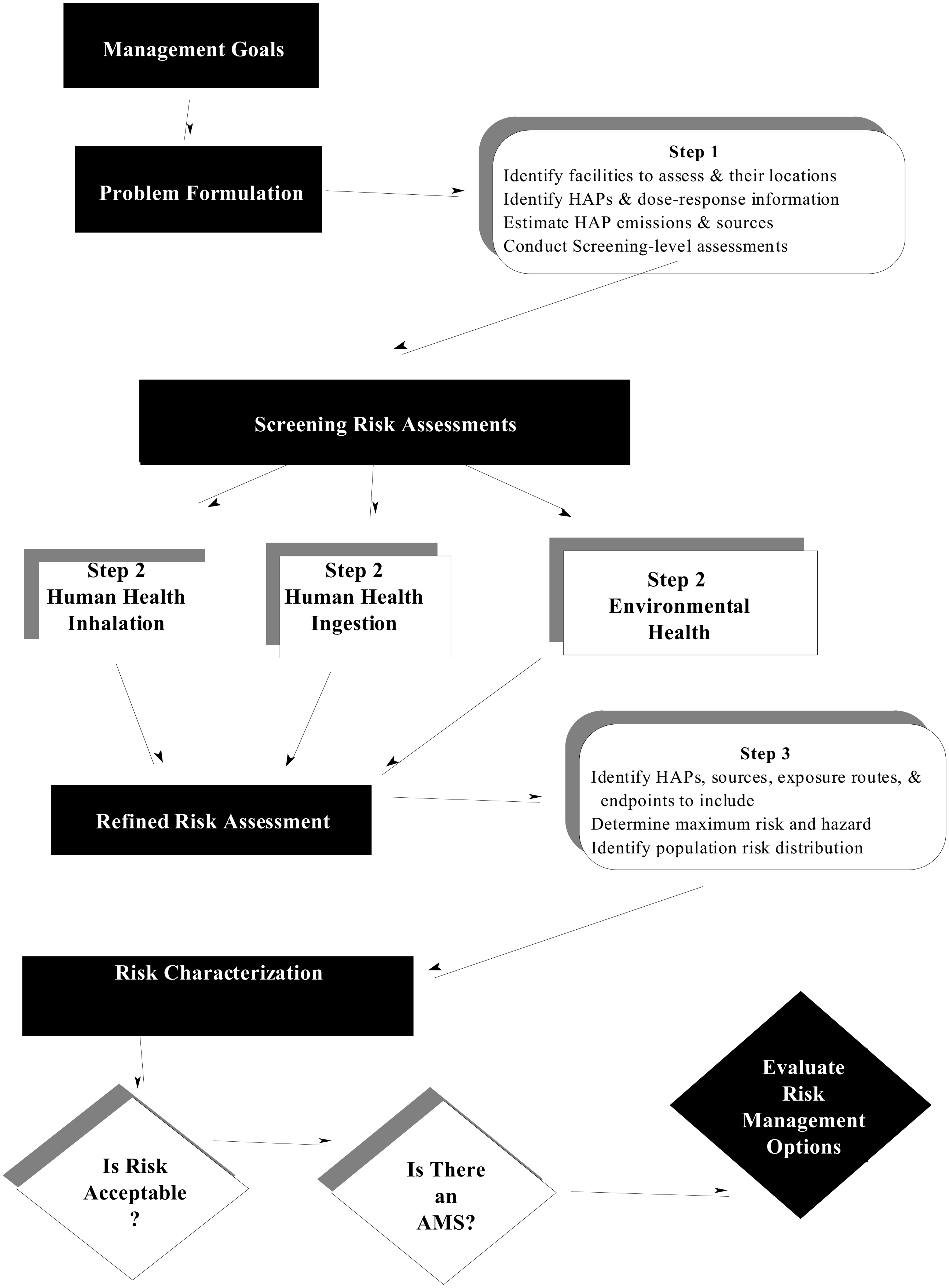
Sections in the main body of this report are organized as follows:

2 Risk Assessment Approach: Problem Formulation
2.1 Toxicity Assessment
2.2 Methods for Estimating Risk or Hazard
2.3 Exposure Assessment
2.4 Analysis of Uncertainty and Variability
3 Analysis Results
3.1 Inhalation Screening Assessment
3.2 Multipathway Exposure Screening Assessment
3.3 Screening Ecological Assessment
3.4 Refined Inhalation Assessment

2.1 Toxicity Assessment

The listed HAP for the coke oven source category is “coke oven emissions”, which is characterized as consisting of a mixture of polycyclic aromatic hydrocarbons (PAHs), organics, and metals. Benzene soluble organics (BSO) comprise the semivolatile organic constituents of coke oven emissions that are soluble in benzene. While some constituents are not benzene-soluble, BSO is considered an appropriate surrogate for quantifying coke oven emissions. In this risk assessment, we used the identified amounts of BSO or MCSO (methylene chloride soluble organic material) as the surrogate for coke oven emissions from the emissions points to be assessed (i.e., battery charging; battery lid, offtake, and door leaks; pushing, quenching, and combustion stacks).

Figure 2-1. Risk Assessment Approach



Although BSO is a good surrogate for coke oven emissions, the emission streams may vary depending upon the source of the emissions. For example, coke oven emissions which occur during the pushing operation pass through a pushing control device, (e.g., a baghouse that captures particulates). Thus the constituent composition of the emission stream that enters the baghouse, (i.e., the coke oven emissions), is different than the emissions stream that emerges from the baghouse. In order to assess risk from these other coke process emission points, HAP constituents identified as being a member of the "universe" of coke oven emissions, were modeled seperately. Emissions from the third source component of this operation, the By-product recovery plant operations, are primarily volatile organics, such as benzene, toluene, and xylene. Risks from these emission points were also estimated on a chemical-specific basis in order to appropriately characterize the risk associated with these sources and their contribution to the facility-level risk and hazard.

2.1.1 Selection of Toxicological Benchmarks

EPA has developed dose-response assessments for chronic exposure to many of the pollutants in this study. These assessments typically specify a reference concentration or dose (RfC or RfD, respectively) to protect against effects other than cancer and/or a unit risk estimate, or URE to estimate the probability of contracting cancer. The RfC (or RfD) is an estimate of an inhalation (or oral) exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risks of deleterious effects during a lifetime. The inhalation URE is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air. For example, if the URE equals $1x10^{-6}$ $(\mu g/m^3)^{-1}$, then as much as 1 excess cancer case would be expected to develop per 1,000,000 people if they are exposed to 1 microgram (µg) of the chemical in 1 cubic meter (m^3) of air daily for a lifetime (U.S. EPA, 2000a). In assessing a substance's carcinogenic potential, EPA evaluates various types of toxicological data and develops a weight-of-evidence (WOE) determination.

To assess inhalation cancer risks at coke plants, EPA developed a unit risk estimate (URE) for the HAP, coke oven emissions, that is appropriate for estimating risks associated with coke oven emissions, including emissions from battery charging, doors, lids, and offtakes; fugitive pushing emissions, and quenching emissions (see below for more complete description of this risk estimate). For the remaining emission sources (i.e., pushing control devices (PCD), combustion stacks, and By-product plants), inhalation or ingestion cancer risk is estimated based on the unit risk estimates (URE) for the individual constituents identified as being emitted from these sources.

In order to assess noncancer hazards, emissions from all emission sources were estimated on a chemical-specific basis using the chronic inhalation health benchmarks such as the RfCs or RfDs when available. These values are not a direct estimator of risk but rather a reference point to gauge potential effects. At lifetime, long-term exposures greater than the RfC (RfD), the potential for adverse health effects increases although, given the uncertainty, the adverse health effect would not necessarily occur (U.S. EPA, 2000a). Currently, no reference concentration exists for the HAP, coke oven emissions, but do exist for some of its constituents. Also, given the lack of acute benchmarks for the major HAPs emitted and the round-the-clock versus batch nature of coke oven processes, (i.e., emissions are more continuous than episodic in nature), analysis of acute (short-term) exposures was not part of this assessment.

2.1.2 Health Effects of Constituents

As described in the *1999 Residual Risk Report to Congress*, hazard identification and dose-response assessment information are drawn from a hierarchy of various sources which have been prioritized according to (1) applicability, (2) conceptual consistency with EPA risk assessment guidelines, and (3) level of review received. The prioritization process was aimed at incorporating into our assessment the best-available science with respect to dose-response information.

In individual risk assessments, deviations from the hierarchy may occur on a pollutant-by-pollutant basis in order to assure the use of assessments most reflective of current toxicological information. As new IRIS assessments progress to the point of providing insights on revised dose-response values, that information is taken into account in ongoing risk assessments. For example, risks for some HAPs, may be calculated using more than one dose-response value in order to be prepared for the impact of updated assessments as they are completed. In other cases, assessments still in draft but having addressed external peer review comments may be considered.

2.1.2.1 Sources of Dose-Response Assessment Information

US Environmental Protection Agency (EPA)

EPA disseminates dose-response assessment information in several forms, depending on the level of internal review. EPA publishes dose-response assessments that have achieved full intra-agency consensus on its Integrated Risk Information System (IRIS), which is regularly updated (EPA, available on-line at www.epa.gov/iris). Many IRIS assessments have also undergone external scientific peer review.

EPA dose-response assessment information which has not been subjected to the IRIS process is disseminated via the Health Effects Assessment Summary Tables (HEAST). The assessment information in HEAST (U.S.EPA 1997) varies in the level of internal and external EPA peer review. Therefore, use of these assessments may be limited.

Agency for Toxic Substances and Disease Registry (ATSDR)

ATSDR, which is part of the US Department of Health and Human Services, develops and publishes Minimal Risk Levels (MRLs) for many toxic substances. The MRL is defined as an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of adverse effects (other than cancer) over a specified duration of exposure. MRLs can be derived for acute, intermediate, and chronic duration exposures by the inhalation and oral routes. ATSDR describes MRLs as media-specific concentrations to be used by health assessors to select environmental contaminants for further evaluation. They are presented with only 1 significant figure, and are considered concentrations below which contaminants are unlikely to pose a health threat. Concentrations above an MRL do not necessarily represent a threat, and MRLs, like RfCs, are therefore not intended for use as predictors of adverse health effects or for setting cleanup levels.

Inhalation MRLs were used in the noncancer portion of this assessment when IRIS RfCs were not available because the MRL concept, definition, and derivation are philosophically consistent (though not identical) with the basis for EPA's RfC. ATSDR publishes MRLs as part of pollutant-specific toxicological profile documents. MRLs are also collected in a table of "comparison values", regularly updated and distributed by ATSDR. MRLs and their accompanying Toxicological Profile Documents undergo external peer review and consideration of public comments.

California Environmental Protection Agency (CalEPA)

The CalEPA Air Resources Board has developed dose-response assessments for many HAPs, based both on carcinogenicity and health effects other than cancer (CalEPA 1999, 2000). The process for developing these assessments is similar to that used by the EPA to develop IRIS values and incorporates significant external scientific peer review. The non-cancer information includes available inhalation health risk guidance values expressed as chronic inhalation reference exposure levels (RELs). CalEPA defines the REL as a concentration level at (or below) which no health effects are anticipated, a concept that is substantially similar to EPA's non-cancer dose-response assessment perspective. This assessment uses chronic RELs in the same way as RfCs when no IRIS or ATSDR values exist.

CalEPA's quantitative dose-response information on carcinogenicity by inhalation exposure is expressed in terms of the URE and defined similarly to EPA's URE. This assessment uses specific CalEPA UREs in the same way as EPA's when no IRIS values exist.

International Agency for Research on Cancer (IARC)

The IARC, a branch of the World Health Organization, coordinates and conducts research on the causes of human cancer and develops scientific strategies for cancer control. The IARC sponsors both epidemiological and laboratory research, and disseminates scientific information through meetings, publications, courses and fellowships.

As part of its mission, the IARC assembles evidence that substances cause cancer in humans and issues judgments on the strength of evidence. "IARC"s degrees of evidence for HAPs are Group 1 (carcinogenic in humans), Group 2A (probably carcinogenic), Group 2B (possibly carcinogenic), Group 3 (not classifiable), and Group 4 (probably not carcinogenic). The categorization scheme may be applied to either single chemicals or mixtures. The IARC does not develop quantitative dose-response indices such as UREs, however.

IARC's WOE for HAPs are included as supporting information for this assessment as a backup to EPA's WOE determinations, which do not cover all HAPs and in some cases may be out-of-date.

Health Effects Assessment Summary Tables (HEAST)

The HEAST are a comprehensive listing of provisional noncarcinogenic and carcinogenic health toxicity values derived by EPA (U.S. EPA, 1997). HEAST benchmarks are considered secondary to those contained in IRIS. Although the health toxicity values in HEAST have undergone review and have the concurrence of individual EPA program offices, either they have not been reviewed as extensively as those in IRIS or they do not have as complete a data set as is required to be listed in IRIS. HEAST benchmarks have not been updated in several years and may not represent Agency-wide consensus information.

2.1.2.2 Prioritization of Data Sources

Some HAPs have been subjected to dose-response assessments by several of the agencies used as sources for this analysis[1]. Because different scientists developed these assessments at different times for purposes that were similar but not identical, it is inevitable that the results are not totally consistent. In considering the available HAP dose-response assessments, and with the objective of identifying a suitable assessment for all HAPs in the risk assessment, EPA applied a consistent default priority scheme to the universe of dose-response information.

RfCs and UREs for chronic inhalation exposure obtained from EPA's IRIS database (or from advanced drafts of peer reviewed IRIS assessments) were given first priority. For HAPs lacking IRIS data, ATSDR MRLs (available only for noncancer effects) received next preference, followed in order by CalEPA RELs and UREs and other cancer and noncancer assessments published in EPA's HEAST.

A list of the universe of HAPs that constitute the HAP, coke oven emissions, is provided in Appendix A, Table A-1. Based on the screening analysis which will be described in Section 3 of this draft Report, arsenic, benzene, and coke oven emissions (measured as BSO) were selected for inclusion in the refined, inhalation analysis. The following sections highlights the human health effects of

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[1] Further information on the development of dose-response assessments by these agencies is available on-line at www.epa.gov/iris, www.atsdr1.atsdr.cdc.gov:8080/mrls.html, www.oehha.ca.gov/air/hot_spots/index.html, and http://193.51.164.11/monoeval/grlist.html.

these 3 pollutants. Health effects information on other constituents considered in the screens may be found in Appendix B.

2.1.2.3 Coke Oven Emissions (BSO)

Epidemiologic studies of coke oven workers reported an increase in cancer of the lung, trachea, bronchus, kidney, prostate, and other sites. EPA classified coke oven emissions as a Group A, known human carcinogen. Chronic (long-term) exposure to coke oven emissions may also result in conjunctivitis, severe dermatitis, and lesions of the respiratory system and digestive system. No information is available on the reproductive or developmental effects of exposures to coke oven emissions.

EPA calculated an inhalation URE of $6.2\text{x}10^{-4}$ $(\mu g/m^3)^{-1}$ (U.S.EPA, 1984). The implications for this assessment are that, if an individual were to continuously breathe air containing coke oven emissions at an average of .002 $\mu g/m^3$ over his or her entire lifetime, that person would theoretically have no more than a 1 in a million increased chance of developing cancer as a direct result (U.S. EPA, 2000a).

Since the derivation of the EPA unit risk estimate in 1984, additional health outcome data have been collected on the occupational cohort on which the dose-response assessment was based. A dose-response assessment using the updated data set (Moolgavkar et al, 1998) developed a cancer unit risk estimate (upper confidence limit) of $1.8\ \text{x}10^{-4}$ $(\mu g/m^3)^{-1}$. The derivation of this value, however, did not comport with general statistical methods for calculating lifetime risk that was adopted by EPA (U.S. EPA, 1984), (e.g., this value did not consider risk of cancer deaths past age 70, while EPA methodology includes risk of cancer deaths through age 85 or greater, as available). Because of this difference in methodology, a direct comparison of the Moolgavkar value with the current EPA URE is inappropriate. Risk estimates for cancer deaths through age 85 are available and would need to be considered in any re-calculation of the URE by EPA. It is presumed that employing EPA methods and including these data would result in a unit risk estimate closer to the current IRIS value. The Moolgavkar estimate, however, differs from the EPA IRIS value only slightly and provides an indication of the size of the variation in values that different analyses may yield.

2.1.2.4 Arsenic

Inorganic arsenic exposure in humans by the inhalation route has been shown to be strongly associated with lung cancer, while ingestion of inorganic arsenic in drinking water by humans has been linked to a form of skin cancer and also to bladder, liver, kidney, and lung cancer. EPA has classified inorganic arsenic as a group A, known human carcinogen, and calculated an inhalation URE of $4.3\text{x}10^{-3}$ $(\mu g/m^3)^{-1}$. Chronic (long-term) inhalation exposure to inorganic arsenic in humans is associated with irritation of the skin and mucous membranes, and neurological injury. Animal studies of inhalation exposure have indicated developmental effects. Chronic oral exposure has resulted in gastrointestinal effects, anemia, peripheral neuropathy, skin lesions, hyperpigmentation, and liver or kidney damage in humans. The reference value used for the assessment of noncancer effects is a California REL value, 3×10^{-5} mg/m^3, based on findings of developmental toxicity in mice (CalEPA, 2000a). The EPA has not set an inhalation reference concentration for inorganic arsenic.

2.1.2.5 Benzene

The EPA has classified benzene as a Group A, known human carcinogen. Increased incidence of leukemia (cancer of the tissues that form white blood cells) has been observed in humans occupationally exposed to benzene. The EPA has derived a range of inhalation cancer unit risk estimates for benzene. The value at the high end of the range was used in this assessment. Chronic (long-term) inhalation exposure has caused various disorders in the blood, including reduced numbers of red blood cells and aplastic anemia, in occupationally exposed humans. Reproductive effects have been reported in women exposed by inhalation to high levels of benzene, and adverse effects on the developing fetus have been observed in animal tests.

EPA calculated a range of 2.2×10^{-6} to 7.8×10^{-6} as the increase in the lifetime cancer risk to an individual who is continuously exposed to 1 µg/m^3 of benzene in the air over his or her lifetime. EPA estimates that, if an individual were to continuously breathe air containing benzene at an average of 0.13 to 0.45 µg/m^3 over his or her entire lifetime, that person would have no more than a 1 in a million increased chance of developing cancer as a direct result (U.S. EPA, 2000a).

Chronic inhalation of certain levels of benzene causes disorders in the blood of humans. Benzene specifically affects bone marrow (the tissues that produce blood cells). Aplastic anemia, excessive bleeding, and damage to the immune system (by changes in blood levels of antibodies and loss of white blood cells) may develop. In animals, chronic inhalation and oral exposure to benzene produce the same effects as seen in humans. Reproductive effects have been reported for women exposed by inhalation to high levels, and adverse effects on the developing fetus have been observed in animal tests. The reference value used for this assessment of noncancer effects was the value on IRIS of 3×10^{-2} mg/m^3, based on hematological effects in humans.

2.2 Methods for Estimating Risk or Hazard

2.2.1 Risk Equations

Cancer risk was calculated as the product of the URE and the exposure concentration, as given in Equation 2-1.

$$\text{Risk} = \frac{\text{URE} \times \text{Concentration} \times \text{ED}}{\text{AT}} \qquad (2\text{-}1)$$

where

Risk = Predicted cancer risk for constituent

URE = Cancer unit risk estimate for constituent
Concentration = Air concentration for constituent
ED = Exposure duration
AT = 70 years

Noncancer hazard was expressed as a Hazard Quotient (HQ) calculated as the ratio of the exposure concentration to the noncancer benchmark, as in Equation 2-2.

$$HQ = \frac{\text{Concentration}}{RfC} \qquad (2\text{-}2)$$

where
HQ = Hazard quotient for constituent
Concentration = Air concentration for constituent
RfC = Reference concentration (in mg/m^3) for constituent

Hazard indices (HIs) were generated by summing HQs across emission sources and HAPs for a given location. For the screening level assessment discussed in Section 3, HIs were calculated by summing the HQs regardless of their target organ. This results in an HI that is considered more health-protective and is done in order to focus the more refined level of the assessment. In the more refined analysis, HIs would be calculated by summing HQs from HAPs only if they have the same target organ. HIs are calculated as given in Equation 2-3.

$$HI = \Sigma(HQ) \qquad (2\text{-}3)$$

where
HI = Hazard index for each emission point or HAP
HQ = Hazard quotient (as calculated in Eq. 2-2) for each HAP

2.2.2 Risk Descriptors

The results of the cancer and noncancer analyses generated several different measures of risk and noncancer hazard. These include individual and population-based measures.

2.2.2.1 Individual Risk

For each site, the analysis identified the maximum risk for populations that, according to the census data, live in the vicinity of each coke facility. This maximum risk is what is referred to as the "maximum individual risk" in the 1999 *Residual Risk Report to Congress* (U.S. EPA, 1999c) and was estimated based on the assumption of a 70 year lifetime exposure duration to HAP emissions. For coke oven emissions, the primary HAP emitted from coke oven sources, were quantified using the surrogate, BSO. Those emission points were all MACT I emission points and the fugitive emissions resulting from the pushing and quenching emission points in MACT II. In the remaining MACT II emission points, (i.e., the pushing control device and the combustion stack), it was not appropriate to model "coke oven emissions" because the emission streams are different. As stated earlier, coke oven emissions which occur during the pushing operation, for example, pass through a pushing control device, (e.g., a baghouse, that captures particulates). Thus the constituent composition of the emission stream that enters the baghouse, (i.e., the coke oven emissions), is different than the emission stream that emerges from the baghouse. In cases such as this, HAP constituents identified as being a member of the "universe" of coke oven emissions and shown by testing to be emitted from this emission point, were modeled independently. The same approach was taken for the combustion stack emission points.

Risk estimates then become an aggregate of risks estimated for each emission point and also across all of the emission points. In the cases where the coke oven emission risk is combined with an individual coke oven constituent risk, risks may be aggregated without concern that "coke oven emissions" risk is being counted twice because risk is aggregated across each emission point using risk estimates from each HAPs constituent. In these cases, the aggregate does not include risk from the HAP, "coke oven emissions". What this says is that our maximally exposed individual is getting exposed from coke oven emissions from some sources and from its the constituents, (e.g., PAHs) from other sources resulting in their aggregate exposure and risk.

2.2.2.2 Population Risk/Hazard

Population-based results express cancer risk and noncancer hazard in terms of the number of people at various risk or hazard index (HI) levels.

- *Noncancer population counts* consist of the number of people experiencing a hazard level indicated by the HI. When there may be additional sources of HAP (beyond the emission sources being evaluated, the Agency has recognized the need to apportion the benchmark when other exposures and total exposure are not or cannot be explicitly considered. Using a default allocation, especially in screening level assessment, eliminates the need to collect background concentration data or data on other exposures. To compensate for other exposures, the precedent from other offices is to allocate between 0.2 and 0.8 of the benchmark to the source of interest depending on the availability of information on other sources of exposure. For the non-cancer screening level assessment done here, a default HI $\leq$ 0.2 was selected as a level that provides a degree of confidence in the health protectiveness of the assessment and allows the scope of a more refined level of assessment to be focused only on those HAPs and sources that exceed the decision criteria.

- *Cancer risk population counts* consist of the number of people experiencing different levels of cancer risk (e.g., $1\text{x}10^{-7}$, $1\text{x}10^{-6}$, $1\text{x}10^{-5}$). The population counts include aggregated (i.e., all chemicals combined) lifetime inhalation cancer risk for each emission source, and aggregated lifetime inhalation cancer risk for each coke plant.

- *Estimation of cancer incidence* gives the expected total annual number of cancer cases across the modeled population. Annual cancer incidence was based on a 70 year lifetime exposure duration and was calculated for each site as the sum of products of cancer risk times population count. This calculation is shown in Equation 2-4.

$$\text{cancer incidence} = \frac{\sum(\text{risk} \times \text{popcount})}{70} \qquad (2\text{-}4)$$

where

cancer incidence = Estimated annual cancer incidence for a given site
risk = Cancer risk predicted for facility at census block centroid
popcount = Estimated number of individuals at risk
70 = Assumed average of human lifetime in years

Cancer incidence represents the number of cancer cases estimated per year of operation based on a 70-year exposure duration and on the assumption that population counts remain the same over the lifetime of the facility (Individuals typically do not occupy the same residence for longer than 9 years on average, and less than 0.1 percent of the population is estimated to reside in one location for greater than 70 years[2]). It is likely that the exposure duration and the population count assumptions when taken together would yield cancer risk estimates that over estimate the risk. For the individual most exposed, the overestimate of risk is probably less than the overestimate of risk for the population in general. But given the residual risk mandate to determine risk to the individual most exposed, this outcome provides us with a degree of confidence that actual cancer risks (were they able to be measured and linked to these emissions) are not likely to exceed the risk estimates projected in this assessment.

2.3 Exposure Assessment

The exposure assessment for the inhalation analysis consisted of estimating exposure concentrations to the entire population within 50 km of each facility. Components of the exposure assessment discussed in the following sections include source characterization, sources and estimation of emission rates, methods for the estimation of air concentrations, a discussion of monitoring, and a discussion of estimating exposure concentrations.

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[2] Exposure Factors Handbook. Vol. III. U.S. Environmental Protection Agency. Office of Research and Development. EPA/600/P-95/002Fc. August 1997.

2.3.1 Source Characterization

The coke plants assessed in this analysis are those determined by EPA to be subject to the 1993 coke oven MACT standards. These batteries chose not to defer the residual risk standard until 2020 and are known as "MACT track" batteries. The facilities included in the assessment are listed in Table 2-1, and their general locations are shown in Figure 2-2.

A typical coke by-product battery consists of adjacent ovens with common side walls made of high quality silica and other types of refractory brick (see Figure 2.3 for typical battery layout). From coal, coke plants produce coke, which is used in blast furnaces for the conversion of iron ore to iron. The process is initiated when coal is loaded into a charging vehicle that moves along the top of the battery and discharges the coal into the ovens. Typically, the individual slot ovens hold between 15 and 25 tons of coal.

Table 2-1. Facilities Included in Coke Ovens Risk Assessment

Facility Name	Facility Location	Universal Transverse Mercator Coordinates (UTMx (km), UTMy (km), Zone)
AK Steel–Middletown	Middletown, OH	725.079, 4373.009, 16
AK Steel–Ashland	Ashland, KY	359.452, 4257.406, 17
Erie Coke	Erie, PA	576.720, 4665.969, 17
Tonawanda	Tonawanda, NY	669.000, 4760.900, 17

The coal is heated for 15 to 30 hours in the absence of air to temperatures approaching 2,000 °F (length of coking time is determined by the coal mixture, moisture content, rate of oven underfiring, and the type of coke to be produced). When demand for coke is low, coking times are extended and temperatures lowered. Battery shutdowns are avoided because cooling the battery results in structural damage. The coking process drives off the volatile organic constituents of the coal as gases and vapors, forming coke which consists almost entirely of carbon. Organic gases and vapors that evolve are removed through an offtake system and are sent to a By-product plant for chemical recovery. At the end of the coking cycle, doors at both ends of the oven are removed, and the incandescent coke is pushed out of the oven by a ram that is extended from the pusher machine. Some facilities have pushing control devices (PCDs) to control emissions associated with pushing. Quench cars carry the coke to a quench tower where the hot coke is deluged with water and cooled. By-product plants recover chemicals distilled from coal during coking and produce coal chemicals, (e.g., tar, ammonia, and benzene).

A coke oven door includes the entire area on the vertical face of a coke oven. There are two doors per oven. Topside port lids are covers that are placed over the openings (charging ports) through which coal is charged into the oven. There are typically three to five lids per oven. These lids remain in place during the coking cycle and are removed only during charging and decarbonization. Offtake systems are piping systems that are stationary and provide a passage for raw coke oven gas from the ovens to the battery's collecting main(s) or to another oven. Charging is the process of filling the oven with a specific weight or volume of coal. Charging starts when the coal first begins to flow into the oven and ends when the last charging port is recapped with a lid. It takes 2 to 6 seconds to charge an oven, and any one oven is charged about every 18 hours (although oven charging may occur more frequently across the entire battery) . Pushing occurs when hot coke is pushed out of the oven onto the quench car. Pushing operations typically occur about every 15 minutes across the length of a typical battery. The emissions from this operation may be especially heavy when the coke is not fully coked, (i.e., when a "green push" occurs). These types of emissions may overwhelm any pushing control devices if they exist.

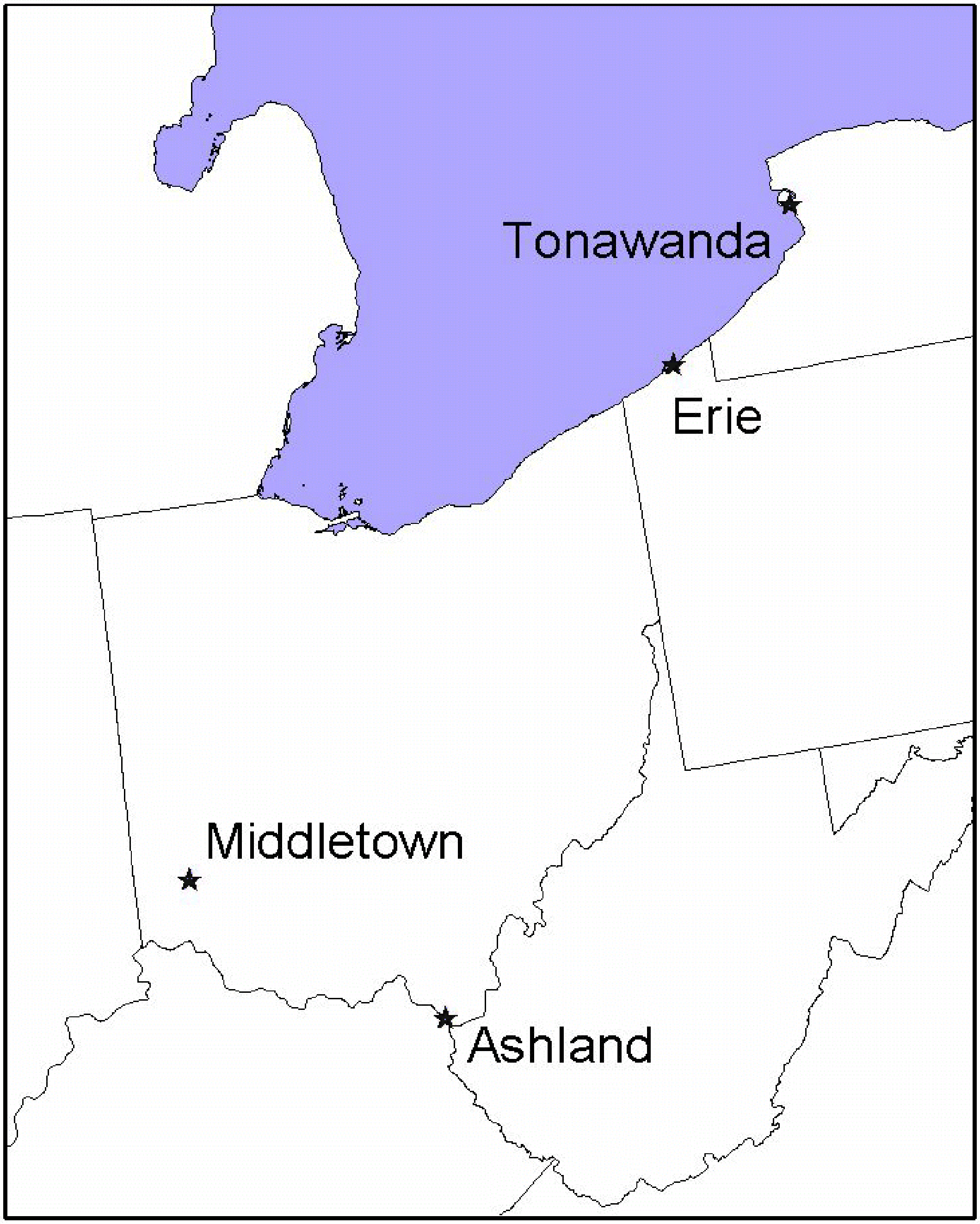

Figure 2-2. Coke plant locations.

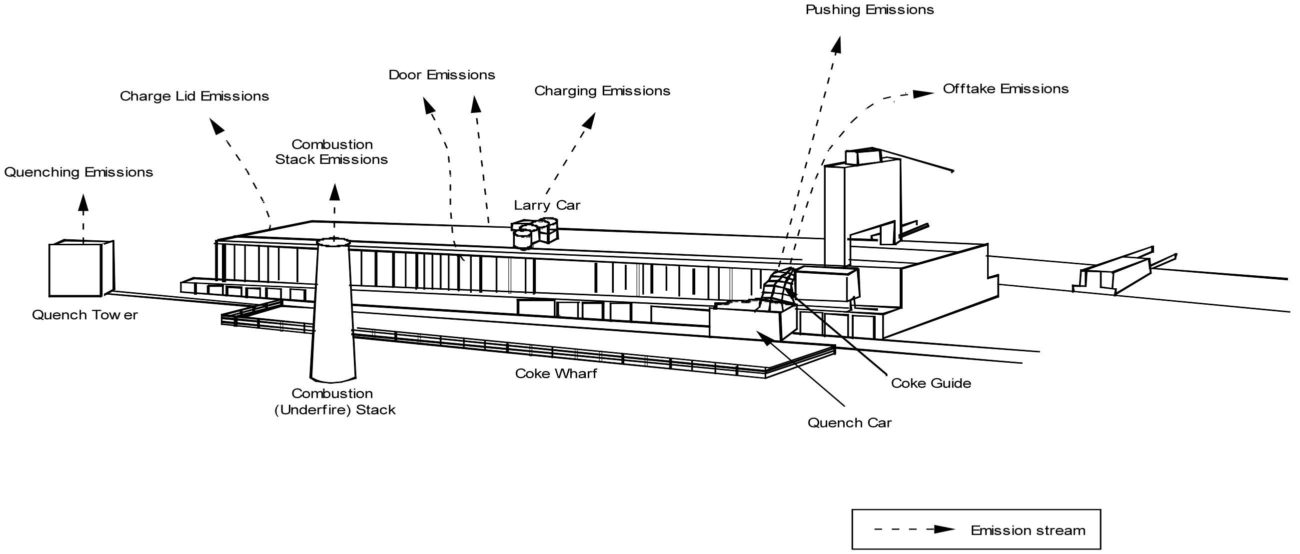

Figure 2-3. Typical Configuration of a Coke Battery

2.3.2 Sources and Estimation of Emission Rates

This risk assessment estimates cancer risks due to the allowable emissions of HAPs, (i.e., the emission levels determined for the MACT standards). These emissions come from coke battery and by-product recovery operations. Emissions were modeled and risks and hazards were assessed for the following emission sources:

MACT I (Final Standards in 1993)
  Covers Coke Batteries (charging, door leaks, lid leaks, offtake leaks)

MACT II (Final Standards in 2003)
  Pushing operations
  Pushing control devices when present
  Combustion stacks

Quenching operations

Benzene NESHAP (Final in 1989)
Includes Coke By-product Plants

Table 2-2 shows the number of each type of emission source at each coke plant addressed in this assessment. At coke plants with pushing control devices (PCD), pushing comprises two types of emissions; fugitive emissions (e.g., uncaptured when PCD overwhelmed by emissions) that occur along the battery, and PCD emissions which typically occur at the PCD outlet which may be some distance from the battery. The fugitives and PCD emissions may have different dispersion characteristics and different emission profiles because of their locations, (i.e., near or remote from a battery). These emissions may be modeled separately from battery emissions, (i.e., they may or may not be included in the plume rise (discussed below). For example, in this assessment, emissions from the By-product recovery part of the facility where chemicals volatilized off during the coking operation are recovered, are not included in the calculated plume rise because these emissions are typically located far from the battery (> 75 meters).

Each facility's By-product recovery plant contains a collection of emission sources comprising different combinations of fugitive equipment leaks, storage tanks, tank truck loading operations, tar loading operations, ammonia stills, and wastewater treatment units. Figures 2-4 through 2-7 show the site layout for each facility, (i.e., the spatial relationship among the various emission points). Facility fence lines and emission source locations were based on site-specific maps and information. Site characterization data were obtained from each facility and included the location and exterior dimensions of each emission source, as well as the location of the facility fence line.

Table 2-2. Number of Emission Sources at Each Coke Oven Facility

Facility	Battery (Charging, Doors, Lids, Offtakes)	Pushing Fugitives	Pushing Control Device	Combustion Stack	Quenching	By-Product Plant
AK Steel–Middletown	1	1	2[b]	1	1	9
AK Steel–Ashland	2[a]	2	2	2	2	15
Erie Coke	2	2	2[c]	1[d]	1	4
Tonawanda	1	1	0	1	2	7

[a] AK Steel- Ashland operates one battery at MACT1 emission levels and the other at LAER emission levels.

[b] The AK Steel–Middletown facility has two PCDs that share three stacks (these are not combustion stacks). The combined emissions from the two PCDs were divided equally among the three stacks for dispersion modeling purposes.

[c] The PCDs at the Erie Coke plant are mobile units and operate along the length of the batteries. Therefore, the dispersion of these PCD emissions were modeled as part of the battery emissions for this facility, (i.e., they are modeled as part of the battery plume). At other facilities, the PCDs are located at some distance from the batteries, and the PCD emissions were modeled with distinct dispersion characteristics.

[d] In most cases, coke plants have one combustion stack per battery. However, the Erie Coke facility has one combustion stack shared by the two batteries.

The risk analyses presented used a combination of allowable emission limits, (i.e., the MACT I and MACT II limits), actual emissions (as reported by each facility), and the lowest achievable emission rates, (i.e., LAER limits). The emission rates (determined for BSO) were estimated using both measured (test) data and ratios. For door leaks, lid and offtake leaks, and charging, the BSO emission rates were based on measurement data, adjusted using battery-specific data such as coal throughput. Emission rates for the individual HAP constituents of coke oven emissions was based on their specific ratio to BSO. For pushing, quenching, and combustion stacks (MACT II), the modeling was based on estimates of emission rates (determined from the methylene chloride extractable organics (MCSO) fraction derived from test data) with HAP constituents again being determined from specific ratios (for purposes of this assessment, the organics and their quantities derived from MCSO extractions was assumed to be similar to those derived from extractions with BSO). Emissions of MCSO for quenching were estimated from the ratio of PAHs:MCSO from the pushing emissions tests because the emissions from pushing and quenching are expected to be similar, (i.e., both occur from the red hot coke after it has been removed from the ovens). Table 2-3 provides a comparison (as percent contribution) of the BSO emissions from each MACT source. The modeling of benzene from By-product plants was estimated from emission factors in AP-42 that were developed primarily from emissions tests and based on estimates of current emissions. Emissions of toluene and xylene were based on their ratio to benzene emissions. Other sources of benzene such as equipment leaks, used site-specific, reported data to estimated emissions. Appendix C describes in more detail the sources and derivations of the emission rates for all of the emission points identified in Table 2-2.

Table 2-3. Percent Contribution of MACT Sources to BSO Emissions

Facility (Battery ID)	MACT I		MACT II			
	BSO Emissions (tons/yr)		Pushing BSO Emissions (tons/yr)		Quenching BSO Emissions (tons/yr)	
AK- Ashland #3	2.56		2.2		1.9	
AK- Ashland #4	2.12	4.68	3.4	5.6	2.9	4.8
AK- Middletown		2.64		2.5		2.1
Erie A	.76		.4		.28	
Erie B	1.16	1.92	.6	1.0	.42	.7
Tonawanda		1.98		2.0		1.0
Source Total		**11.22**		**11.1**		**8.6**
MACT Total BSO (Percent Contribution)		**11.22** **(36)**				**19.7** **(64)**

BSO emissions data taken from Tables C-5, C-7, C-11

It should be noted that when emission rates for coke oven emission constituents such as PAHs are modeled separately from BSO, it is because the emission source alters the emission stream sufficiently that is may no longer be considered “coke oven emissions”, (e.g., after filtering in pushing control device (PCD)). Constituents are also modeled when it was necessary to determine non-cancer effects or non-inhalation exposures. In these cases, BSO, (i.e., the surrogate HAP for “coke oven emissions”) is not considered and there is no double counting of results.

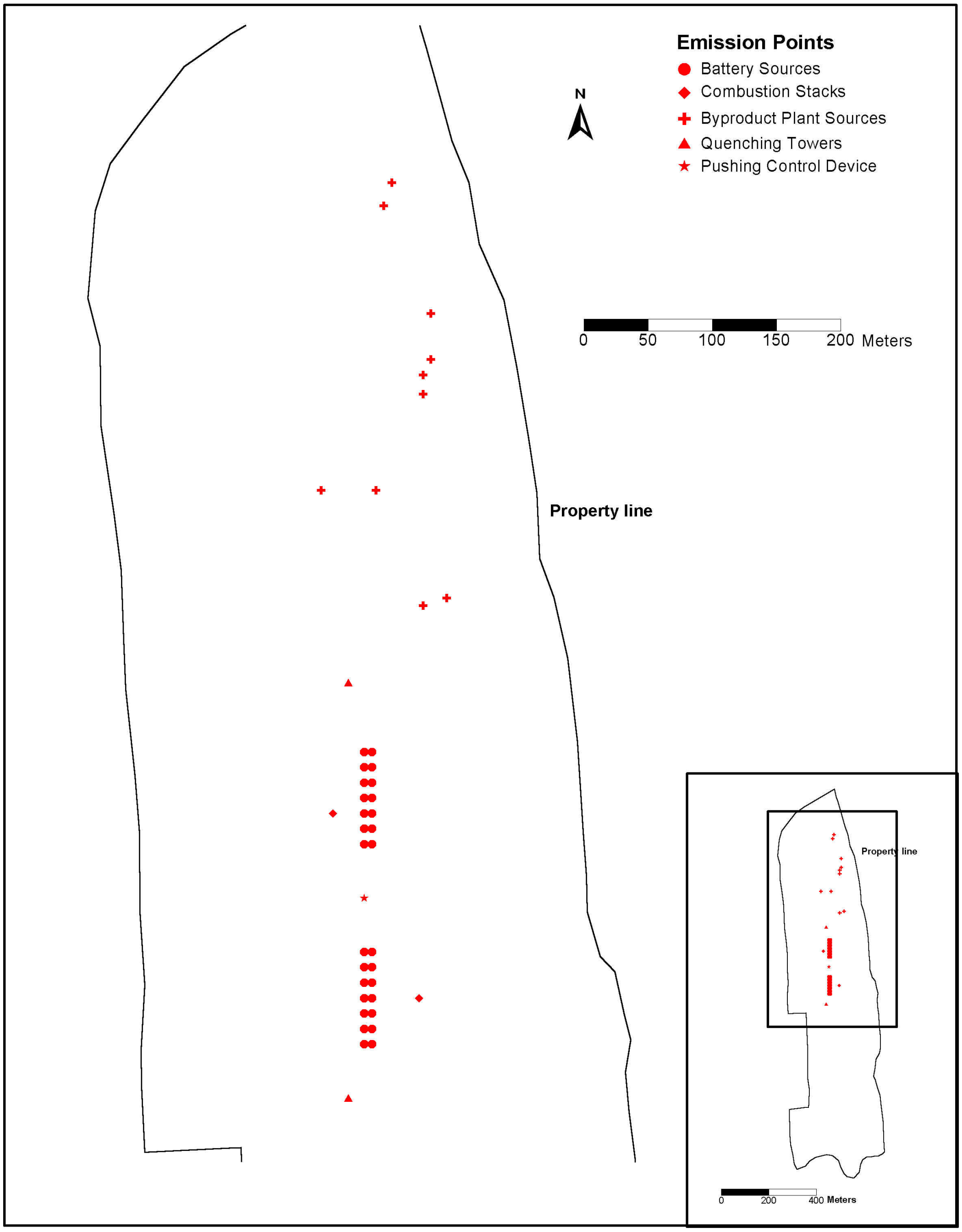

Figure 2-4. Site layout for AK Steel - Ashland

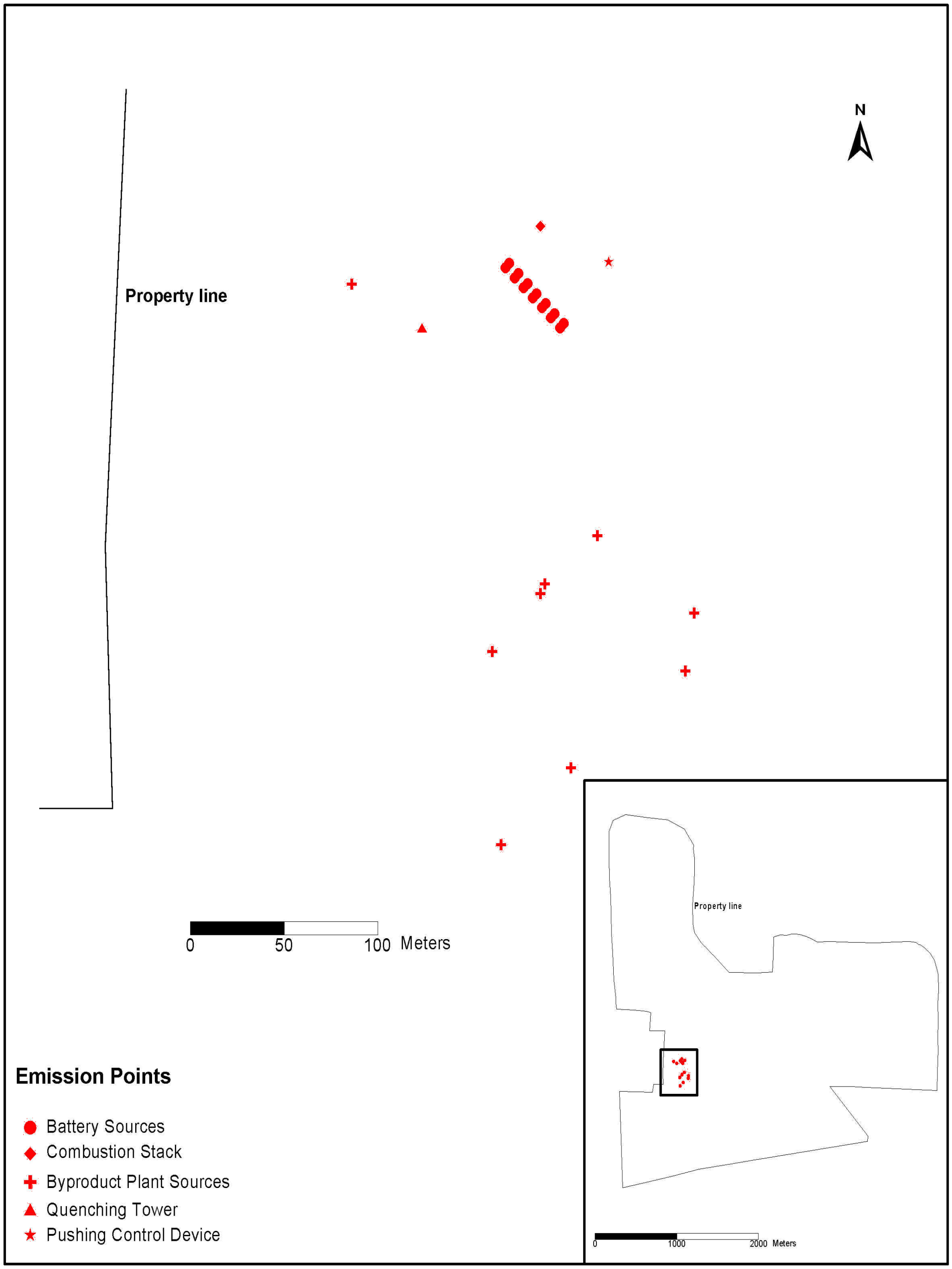

Figure 2-5. Site layout for AK Steel - Middletown

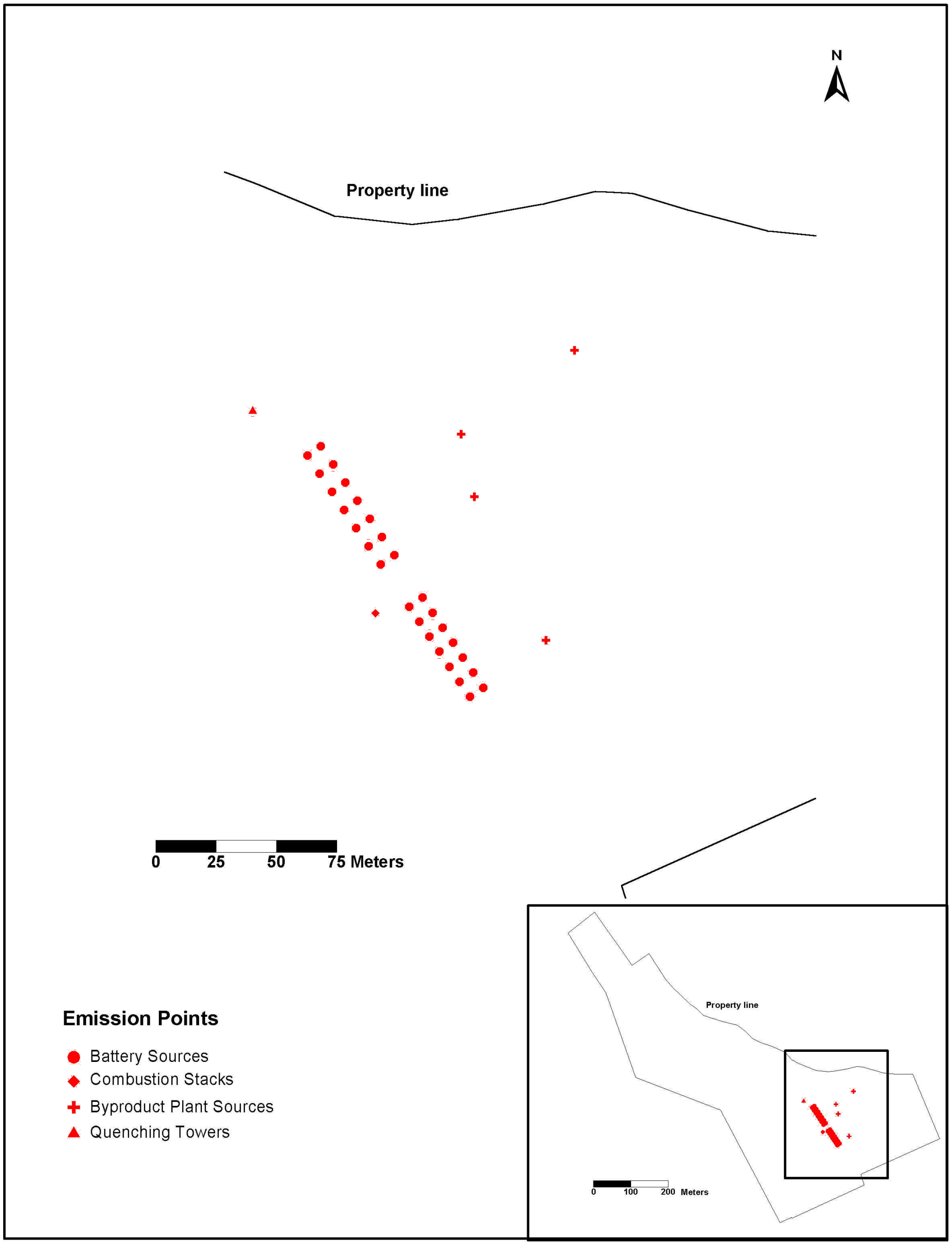

Figure 2-6. Site layout for Erie Coke

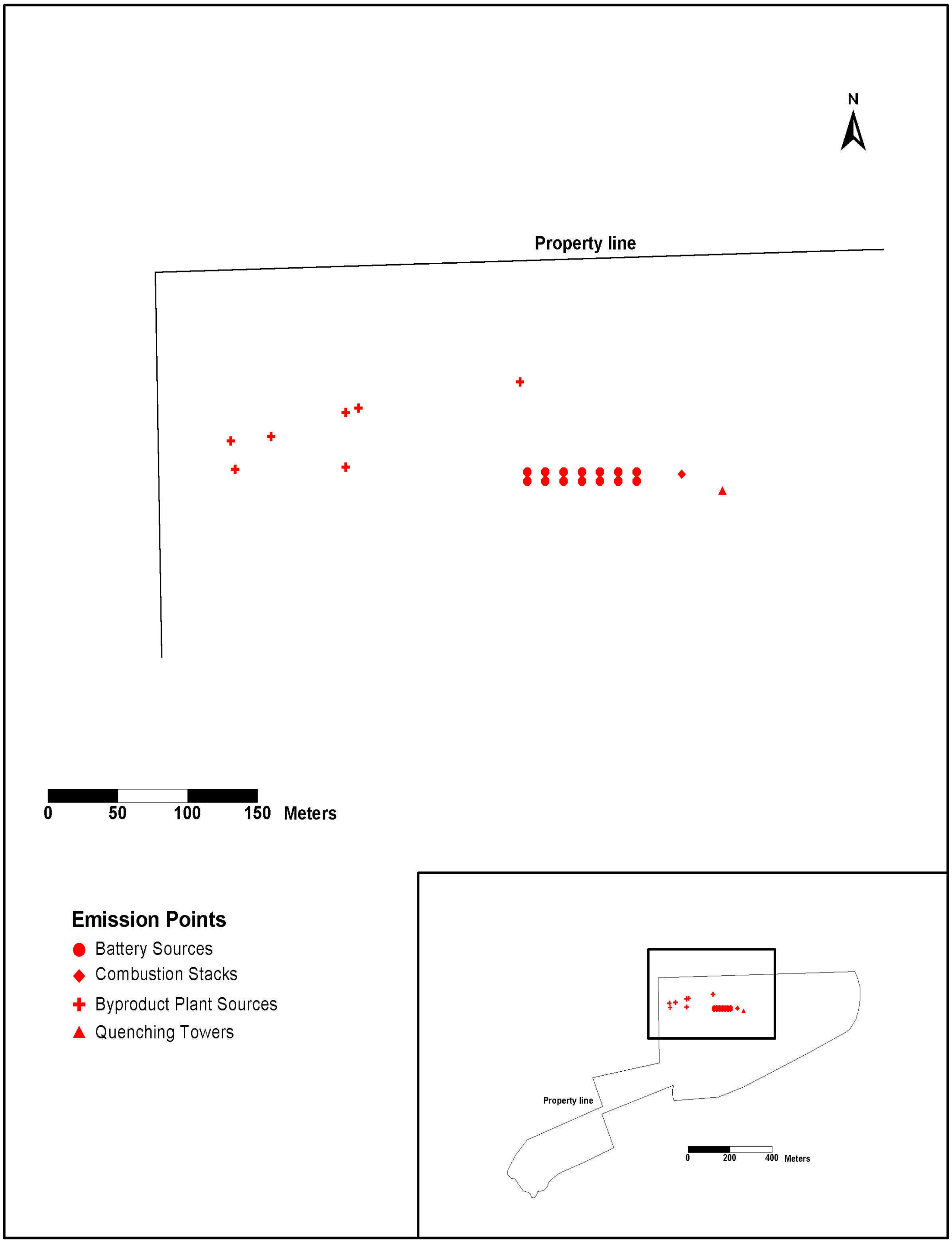

Figure 2-7. Site layout for Tonawanda

Source-specific emission rates were estimated using the following general methods. Appendix C documents the derivation of emission rates and presents tables of the emission rates used in this risk assessment.

- **Charging.** Charging emissions (which occur in the center of the top of a coke battery) were estimated based on the mid-range of upper- and lower-bound emission factors from AP-42 (U.S. EPA, 2001a), (i.e., (0.009 lb BSO per charge for 10 seconds of emissions) and site-specific information on the number of charges (number of ovens divided by the coking cycle time). See Tables C-4 to C-6 for the various emission limits and estimates.

- **Lid and Offtake Leaks.** These emissions (which emanate from the top of the battery) were estimated based on the mid-range emission factor from AP-42, (i.e., (0.0075 lb BSO/h per leak) and the allowable number of leaks. Site-specific information for the number of lids and offtakes on the battery was used. See Tables C-4 to C-6 for the various emission limits and estimates.

- **Door Leaks.** These emission (which emanate from the sides of the battery) used factors from the revised AP-42 (in lb BSO/h per leak) and site-specific information on the number of doors on the battery. Emission estimates were calculated using allowable limits. See Tables C-4 to C-6 for the various emission limits and estimates. These estimates used the following emission factors:

  – <u>Leaks visible from the yard (0.04 lb/h)</u>: Method 303 (Appendix C Reference: US EPA, 1999c), requires a certified observer to walk next to the battery and record the visible emissions using leak grades from 0.5 to 3. These numbers are then used to monitor compliance with MACT leak requirements. The standard observations are made from a distance of approximately 50 to 75 feet from the oven doors. These observations are called the "yard" visible emissions.

  – <u>Leaks visible from the bench and not the yard (6% of the doors at 0.023 lb/h)</u>. An observer may move closer to the oven doors, (i.e., the platform area immediately adjacent to an oven door) and record visible emissions from this distance. These recordings are referred to as "bench" visible emissions. Leaks around oven seals are more likely to be seen during these observations than during yard observations.

- **Pushing Emissions.** These emission occur on the side of the battery when the doors are open and the coke is pushed out. Emission factors for methylene-chloride-extractable organics from two EPA tests (U.S. EPA 1999a, U.S. EPA 1999b) for three kinds of pushes, (i.e., non-green, moderately green, and severely green), were used in estimating pushing emissions ("Greenness" refers to the degree to which complete coking is achieved. Low greenness means the coal is fully coked. High greenness means volatiles are still being evolved and indicates that higher levels of coke oven emission constituents, such as PAHs, are present.). The following assumptions were used: 94.5 percent non-green, 5 percent moderately green, and 0.5 percent severely green pushes with assumed 90 percent control device capture efficiency for non-green pushes, 40 percent efficiency for moderately green, and 10 percent efficiency for severely green.

- **Quenching Emissions.** These emission occur at the quench tower located at a distance (approximately 50+ meters) from the battery. Emission factors for methylene-chloride-extractable organics from one EPA test were used in estimating quenching emissions: 0.018 lb/ton coal for severely green pushes and 0.007 lb/ton for not severely green pushes. The following assumptions were used: 94.5 percent nongreen, 5 percent moderately green, and 0.5 percent severely green pushes.

- **Combustion Stack Emissions.** These emissions come from the combustion stacks which range in height from 54 to 76 meters, and are usually located some distance from the batteries. Emission factors for methylene-chloride-extractable organics were developed from one EPA test (see Appendix C). Emission ratios were calculated based on actual stack flow rate. Emissions were scaled up from low opacity (1.7 percent opacity) during the test to an average of 5 percent opacity. Emissions from these stacks come from the burning of the fuel used to fire the coke ovens.

- **By-Product Recovery Plant Emissions.** These emissions are primarily the organic HAP emissions which occur at the By-product component of the facility which is located away from the coke battery. Emission factors for equipment leaks from AP-42 as well as site-specific data were used in emission estimation for process and fugitive equipment leaks from equipment in benzene service. Fugitive emissions of toluene and xylene were estimated based on their ratio to benzene.

2.3.3 Estimation of Air Concentrations

This report presents the estimates of hazard or risk to the general population surrounding four coke oven facilities determined by EPA to be subject to the 1993 coke oven MACT standards. People living near these plants are potentially exposed to coke oven emissions, its constituent HAPs, and the organic emissions from the By-product recovery plant. The study area for each plant is defined by a 50 km radius from the center of the coke plant.

Emissions considered in this risk assessment are assumed to be continuous although not all coke ovens in a battery are at the same stage of the coking process. Some ovens are being charged, some are in the coking stage, while others are pushing the hot coke onto the quench car. While these steps might suggest that emissions from these sources are not continuous, the contribution of each source across a battery with potentially 70+ ovens, is more accurately described as continuous. For example, the charging of coal into an oven is required to be completed in 12 seconds and this activity only occurs after the coke has been "pushed" after completion of the coking process. Along a typical battery, pushing occurs approximately every 15 minutes. So while these emissions may appear to happen at intervals, the intervals are small (i.e., the emissions do not have defined emission peaks) and the overall impact of a single source of emissions on an aggregate plume rising up from these sources may not cause large variations in the emission plume rising above a battery. Therefore, for this risk assessment, we assumed emissions from the battery operations were continuous over the year and not batched.

An atmospheric dispersion modeling approach was developed to estimate atmospheric concentrations and surface deposition rates of vapor-phase and particulate air pollutants across the 50 km study area. Because of the relatively, large, rectangular shape of a typical coke battery and the large quantities of heat associated with several of the emission points at coke oven facilities, the standard regulatory dispersion model used in our risk assessments, ISC, is unable to realistically simulate the enhanced plume rise associated with these uniquely shaped sources and their highly buoyant emissions. To better simulate emissions from these sources, emissions were modeled in a two step process; first to determine the plume height and second to simulate the dispersion, transport and deposition of the HAP or HAPs. The first step used the EPA's Buoyant Line Plume (BLP) model (U.S. EPA, 1980); the second step used EPA's standard dispersion model, (i.e., the Industrial Source Complex Short Term (ISCST3) model (U.S. EPA, 1995, 1996)).

In modeling the plume rise using BLP, only those emission points that are close enough to the battery to be captured in the hot, buoyant plume, were included. For this analysis, those emission points included the doors, topside lid and offtake leaks, charging, and pushing emissions. All other emissions not included in the plume rise, (e.g., emissions from the By-product recovery plant) were modeled directly with the ISC model. Typically, emission sources at the By-product recovery Plant were modeled as area and volume sources, while other emission sources, such as coke oven batteries, combustion stacks, quench towers, and pushing control devices, were modeled as point sources.

As stated above, coke facilities produce significant heat from large, parallel batteries which behave as low-level buoyant line sources. In their typical configuration, (i.e., parallel-line sources), plume rise is enhanced because ambient air is not fully entrained into the plume. In order to more accurately describe the downwind transport and plume growth that would occur as emissions were released from these very large, rectangular structures, (i.e., the batteries), the emissions input into the BLP model were spread out over a wide horizontal area. This was accomplished by proportioning plume emissions into a series of point sources or "representative " stacks which allow the unique shape of the battery to be spatially represented by the overlap of each "stack's" emissions. Each coke oven battery was modeled as a set of 14 stacks (two rows, seven point sources per row) to represent emission releases. One-fourteenth of the total area of the battery is then allocated to each stack, and an effective stack diameter is determined. Figure D-2 in Appendix D depicts the model simulated layout for a typical battery configuration. The number of stacks used to simulate the batteries was determined based on a sensitivity analysis which is described more fully in Appendix E. The output of the BLP model, (i.e., hourly plume height information generated), was used as an input into the ISCST3 model.

ISCST3 is a steady-state Gaussian plume dispersion model capable of assessing pollutant concentrations and deposition flux (resulting from dry and/or wet processes) for nonreactive pollutants (U.S. EPA, 1995). In addition, the ISCST3 model is capable of simulating air concentrations in simple, intermediate, and moderately complex terrain, and is considered the more appropriate model to use when doing a site-specific risk assessment because, for example, it allows for the input of detailed, hourly meteorological data.

The ISCST3 output consists of a polar grid of chemical-specific air concentrations[3] for each emission source at each facility. For each receptor, annual average concentrations and deposition rates of coke oven contaminants (both particle and vapor phases) may be estimated by averaging (or summing for deposition) over all of the modeled hours for each year. Subsequently, the annual average concentrations and deposition rates for the five year period are determined by averaging the five individual years. Five years corresponds to the timeframe of the meteorological data used in dispersion modeling. The concentrations and deposition rates for each emission source is then interpolated to a population centroid, (e.g., census block centroid), to generate spatially-explicit population based air concentrations.

Appendix D provides a description of the dispersion modeling for the coke ovens assessment; Appendix E provides plume rise calculations; and Appendix F presents the source parameters (e.g., stack heights, exit velocities, source configurations) used in the dispersion modeling. Source parameters describe the physical characteristics of the various emission points, which affect the dispersion of emissions.

2.3.4 Monitoring Data

Monitoring data may be useful for evaluating modeling approaches to estimate ambient concentrations for conducting an assessment of this type. In an analysis that tries to compare monitoring to modeling results, it is important that certain characteristics of the monitoring data exist before a comparative analysis should occur. Some of the more important characteristics are as follows:

- The monitor should be designed to measure at least one of the HAPs known to be emitted from the facility modeled.
- The monitoring method should be sensitive enough to measure the anticipated ambient concentration of HAP from the facility in question.

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[3] The ISC output was based on a standard emission rate input of 1 (g/s) for each source. The outputs, (i.e., unitized air concentrations in (g/s)/(µg/m^3) at each receptor grid location is multiplied by the actual HAP/source emission rate (in g/s) to yield HAP/source air concentrations (in µg/m^3) at each receptor grid point. These air concentrations can also be partitioned between vapor and particulate components.

- The monitor location should be known, (i.e., the lat/long coordinates, and should be encompassed by the modeling study area (usually within 50 km).
- The monitoring data should, ideally, be contemporaneous or as close as possible with the emission estimates which drive the modeling. For short term emission events, site-specific meteorological data are needed to interpret the monitoring results..
- The monitored data should be identified with or linked to the facility modeled. This may be accomplished by knowing that the monitor was intentionally placed to capture specific facility emissions, or that the HAP being monitored is unique to the facility that was modeled. This determination should also consider the degree to which other HAP sources in the vicinity might contribute to the background levels of the HAP. Ideally, for the most utility in evaluating the modeling approach, the monitoring data should be dominated by contributions from the source or facility being assessed.

For this risk analysis, no monitoring data exist which meet these criteria. Therefore, it was not possible to evaluate the ambient concentrations estimated by the modeling using monitoring data.

In 1991, EPA Regions 3, 4, and 5 established the Tri-State Geographic Initiative (www.epa.gov/region5/air/tristate/tristate.htm) to focus on those counties in the 3 states (Kentucky, Ohio and West Virginia) where there may be significant exposures to their respective populations because of the presence of 4 major urban areas and many large industries. Six industrial "clusters" were identified and rank ordered for study. Each cluster study includes air toxics monitoring, collection of meteorological data, and risk assessments (modeling). To date, 2 of the clusters have collected data but neither of these were in close enough proximity to the one coke facility (AK-Steel Ashland) to make these data useful for evaluating the modeling described in this report. A later cluster analysis (Cluster 4) may generate data of use because it will be conducted in closer proximity to this facility.

2.3.5 Estimating Exposure Concentrations and Risk

In the exposure characterization, the HAP concentration and study population are spatially integrated to characterize exposure. In characterizing the exposed population, information about the population is derived from the 2000 U.S. Census data (Bureau of the Census, 2001). These data indicate the number of individuals living in each Census block and block group. Census blocks are roughly analogous to city blocks, and block groups are aggregations of contiguous blocks. For this assessment, the number of people residing in each block and the geographical center of each block, (i.e., the population exposure analyses are based on centroid of a census blocks) are used with the assumption that the population in each census block is uniformly distributed across a block. In this assessment, air modeling yields estimates of air concentrations across the modeling grid. These air concentration estimates are matched up with the census block data in order to generate the population-weighted cumulative risk distribution for each site and source. From these data (presented in Appendix I), a risk isopleth for each facility (Figures 3-1 to 3-4) is developed showing the spatial extent of the risk distribution. The estimated ambient concentration data may also be used in a variety of ways and applications. For example, in the screening-level assessment, the maximum estimated concentration for all HAP/source combinations assumed that a single receptor was being exposed to the combined impacts of all HAP/source combinations. Using this health protective approach, different parameters may be screened out for inclusion in the refined analysis. The ambient concentration data may also be used as the starting point for conduction human multipathway or ecological screening-level risk or hazard assessments. These later analyses are discussed more completely in Section 3.

As stated, the risk assessed is based on the assumption that each receptor is exposed for 70 years to outdoor air concentration levels, (i.e., all receptors are assumed to live in the vicinity of each facility for a 70 year exposure duration). However, because not all individuals living in the vicinity of these coke facilities experience the same exposure, cancer risk may also be estimated using a probabilistic analysis that varies exposure duration. A full probablistic analysis which varies exposure duration was not done for this assessment. In order to provide a sense of how exposure duration may affect risk results, we applied the exposure duration factor for the average residency time (9 years) to the maximum risk level estimated. Table 3-12 presents the risk resulting from this application.

There are additional exposure parameters that may provide more information on possible variations in exposure (and risk) that may be seen, (e.g., changing exposure durations, considering activity patterns or breathing rate adjustments). In this assessment reported here, we did not conduct a more refined level of analysis on exposure. In our previous, nationwide, modeling study[4], we concluded that while the predicted, average, long-term, population exposures may be biased high by about 25% if human activity patterns are not considered, typical biases are much less, and the highest individual exposures are not generally affected at all. Given that level of bias and our regulatory focus on the high-end exposed population, we concluded that a more refined level of exposure analysis was not necessary. More refined exposure assessments may be more appropriate in other residual risk assessments.

2.4 Analysis of Uncertainty and Variability

The residual risk decision will focus on those emission points associated with MACT I, (i.e., charging, lid, offtake and door leak emissions), although this assessment included the entire facility. Therefore, we have focused the uncertainty analysis on the emissions from the MACT I relevant emission points. In general, data are limited in developing benzene soluble organic (BSO) emissions estimates, and given the expense, source testing was limited to few facilities or batteries with limited repeat testing. As a result, the data used to generate EPA's emission factors were evaluated to generate estimates of uncertainty in those factors.

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[4] NATA Report Jan 2001; page 86; Table 4-13. This draft report which was reviewed by the SAB may be found at: www.epa.gov/ttn/atw/sab/sabrev.html

For this uncertainty analysis, emissions from leaking doors are estimated using the following equation.

ELD = (Doors)[(PLDvy * ERvy) + (PLDvb * ERvb) + (PLDnv * ERnv)]

ELD = Emissions from leaking doors (lb/hr)
Doors = Number of Doors
PLDvy = Percent leaking doors visible from yard
ERvy = Emission rate from yard visible leaks (lb/hr)
PLDvb = Percent leaking doors visible from bench
ERvb = Emission rate from bench visible leaking doors (lb/hr)
PLDnv = Percent of non-visible leaking doors = [1-(PLDvy + PLDvb)]
ERnv = Emissions from non-visible leaking doors (lb/hr)

The MACT I sets allowable limits (see Table C-3) for percent of leaking doors (as monitored by EPA Method 303) at 5 percent. The residual risk assessment is designed to evaluate the risks which are associated with the emissions allowable under the MACT program. Therefore, percent leaking doors visible from the yard [5] are assumed to be at 5 percent and are not considered either uncertain or variable. The uncertainty (variability) associated with the other parameters were evaluated in the following sections to estimate the uncertainty in leaking door emissions estimates.

2.4.1 Emission Rate for Door Leaks Visible from Yard (ERvy)

To estimate the uncertainty in emissions from door leaks as collected using Method 303, the original test data were evaluated. Table 2-4 presents the individual run data for different grades of door leaks from two different studies (U.S. EPA, 2001a). Leaks which are visible from the yard are assumed to be of leak grade Categories 0.5 to 3. At the MACT performance level, it is expected that these door leaks would be dominated by Category 0.5 and 1 leaks, with some Category 2 leaks and few Category 3 leaks. The available data for Category leaks 0.5 to 3 presented in Table 2-4 are dominated by Category 0.5 and 1 (n=18), with few Category 2 and 3 leaks (n= 5 and 3 respectively). Therefore, it is assumed that the data are representative of the frequency of occurrence and of the emissions rates which are likely to be experienced.

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[5] Method 303 (Appendix C Reference: US EPA, 1999c), requires a certified observer to walk next to the battery and record the visible emissions using leak grades from 0.5 to 3. These numbers are then used to monitor compliance with MACT leak requirements. The standard observations are made from a distance of approximately 50 to 75 feet from the oven doors. These observations are called the "yard" visible emissions.

Table 2-4. Individual Run Data for Different Grades of Door Leaks from Two Studies

Leak Category	BSO lbs/hr	Avg ±SD	Relative SD	Median	Leak Category	BSO lbs/hr	Avg ± SD	Relative SD	Median
0[1]	0.002				1	0.047			
0[1]	0.004				1	0.038			
0[1]	0.005				1	0.024			
0[2]	0.0075				1	0.019			
		0.005 ±0.0023	**0.46**	**0.0045**	1	0.03			
0.5	0.052				1	0.022			
0.5	0.035				1	0.02			
0.5	0.018				1	0.02			
0.5	0.026				1	0.013			
0.5	0.016						**0.027 ±0.011**	**0.40**	**0.022**
0.5	0.023				2	0.028			
0.5	0.018				2	0.028			
0.5	0.01				2	0.065			
0.5	0.012				2	0.064			
		0.023 ±0.013	**0.57**	**0.018**	2	0.12			
							0.061 ±0.038	**0.62**	**0.064**
					3	0.096			
					3	0.059			
					3	0.173			
							0.109 ±0.058	**0.53**	**0.096**

Data from U.S.EPA, 2001a)

[1] Empty oven when tested

[2] No visible emissions

To understand the emissions from yard visible leaks, the data for grades 0.5 to 3 were combined and analyzed using z-score regression. The results show that a lognormal distribution is reasonable and preferred over a normal distribution with a $R^2 = 0.957$ for lognormal and $R^2 = 0.72$ for normal. Based on this preferred distribution, a median of 0.03 and a geometric standard deviation (GSD) of 2.05 were estimated from the data.

2.4.2 Emission Rate for Door Leaks Visible from Bench (PLDvb)

Method 303 (the standard method for tracking compliance) relies on observing visible oven leaks from the yard, (i.e., each reading is taken at a set distance from the battery and while the reader is walking slowly the length of the battery). However, it is well documented that additional leaks may be observed from the bench [6]. To fully characterize emissions, the percent of doors which are leaking but not detected using yard observations, should also be determined. To estimate the uncertainty in estimating bench-visible leaking doors, we looked at data collected at two facilities (USX and Clairton) on a total of five batteries. For these facilities, yard and bench observations were collected simultaneously. The difference between these two measures is called the "bench-only visible leaks". Table 2-5 summarizes these data. An evaluation of the data indicated that the inter-plant variability was significant while inter-battery variability was not. This is illustrated in Figure 2-8, where the z-score plot of the data show that the mean (intercept) and standard deviation (slope) differ between the two facilities, while differences within a facility are not as great.

Table 2-5. Summary of Bench Visible Oven Door Leaks

Facility-Battery No.	No. of Observations	Average Percent Visible Leaks ± SD
Clairton - 7	7	6.3 ± 1.8
Clairton - 8	13	5.4 ± 3.1
Clairton - 9	4	5.7 ± 2.3
USX - 3	7	3.6 ± 1.9
USX - 4	23	2.3 ± 1.9

Since the two facilities were different, the data could not be combined into one overall data set. Therefore, data within each plant were combined, and the plants were evaluated separately. The data

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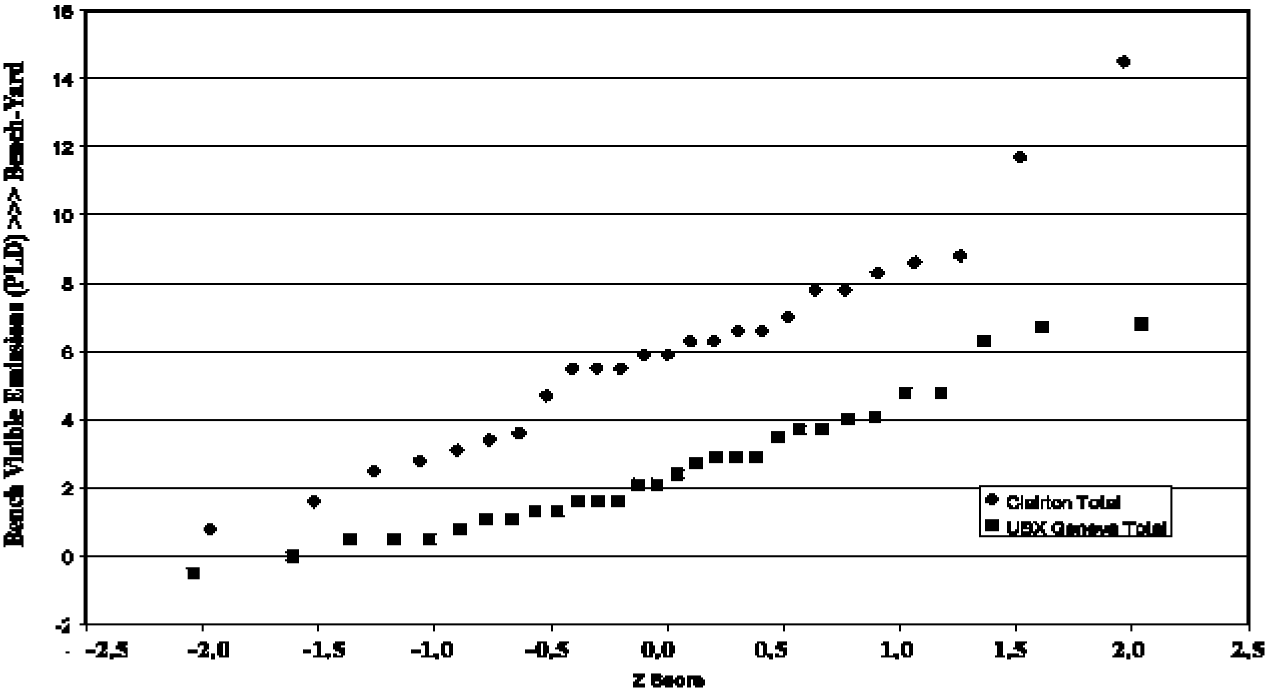
[6] An observer may move closer to the oven doors, (i.e., the platform area immediately adjacent to an oven door) and record visible emissions from this distance. These recordings are referred to as "bench" visible emissions. Leaks around oven seals are more likely to be seen during these observations than during yard observations.

were statistically evaluated, and using a Shapiro-Wilks test, we could not reject normality at a 5% significant level. Therefore, the data were treated as being normally distributed.

Figure 2-8 Comparison of Bench-visible Emissions (PLD) for Clairton and USX



For each plant, we regressed the data for bench visible leaks against the yard visible leak data. The data for both Clairton and USX were shown to be directly proportional, so that the number of bench-only visible leaks could be predicted by the number of yard-visible leaks. Since the residual risk assessment is concerned with risks allowable under the MACT, we estimated the percent of bench visible leaking doors which would be associated with a 5% rate of yard visible leaking doors.

Therefore, for each facility, we forecasted the bench visible leak rate using our regression for the best estimate of the bench visible leak rate and the standard error of that forecast (STEYX) as a measure of the uncertainty. For Clairton, the forecast rate for bench-only leaks was 6.0 with a standard error of 2.4. For USX, the forecasted bench-only visible leak rate was 2.5 with a standard error of 1.9. Since each of these plants was assumed to be equally representative, we took the average of the two (4.25%) to represent the estimated average bench-only visible leaks corresponding to the MACT rate limit of 5 % for yard visible leaks. To estimate the overall uncertainty we "pooled" the variance based on sample size and got a standard error of 2.2. Furthermore, on only one occasion did the yard visible leak rate exceed the bench visible rate when both were below 3 percent. It is not likely that this would occur when yard visible leak detection is 5 percent. Therefore, to estimate the uncertainty in the percent of bench-only visible leaks we used a normal distribution with a mean of 4.25 and a standard deviation of 2.2, truncated at zero.

2.4.3 Emission Rate from Bench Visible Leaking Doors (Ervb)

Bench-only visible leaks are assumed to be of grade 0.5 (U.S.EPA, 2001a) . Therefore, the data presented in Table 2-5 for leak grade 0.5, were evaluated to estimate the uncertainty in emissions. Using a z-score regression technique, the data were shown to be preferentially described by a lognormal distribution (R2 = 0.975) over a normal distribution (R2 = 0.86). The median and GSD of the data were estimated as 0.021 and 1.7, respectively.

2.4.4 Percent of Non-Visible Leaking Doors (PLDnv = [1-(PLDvy + PLDvb)])

This is directly calculated from the yard-visible and bench-only visible leaking doors. The uncertainty in those estimates therefore, yields an estimate in the uncertainty in the percent non-leaking doors.

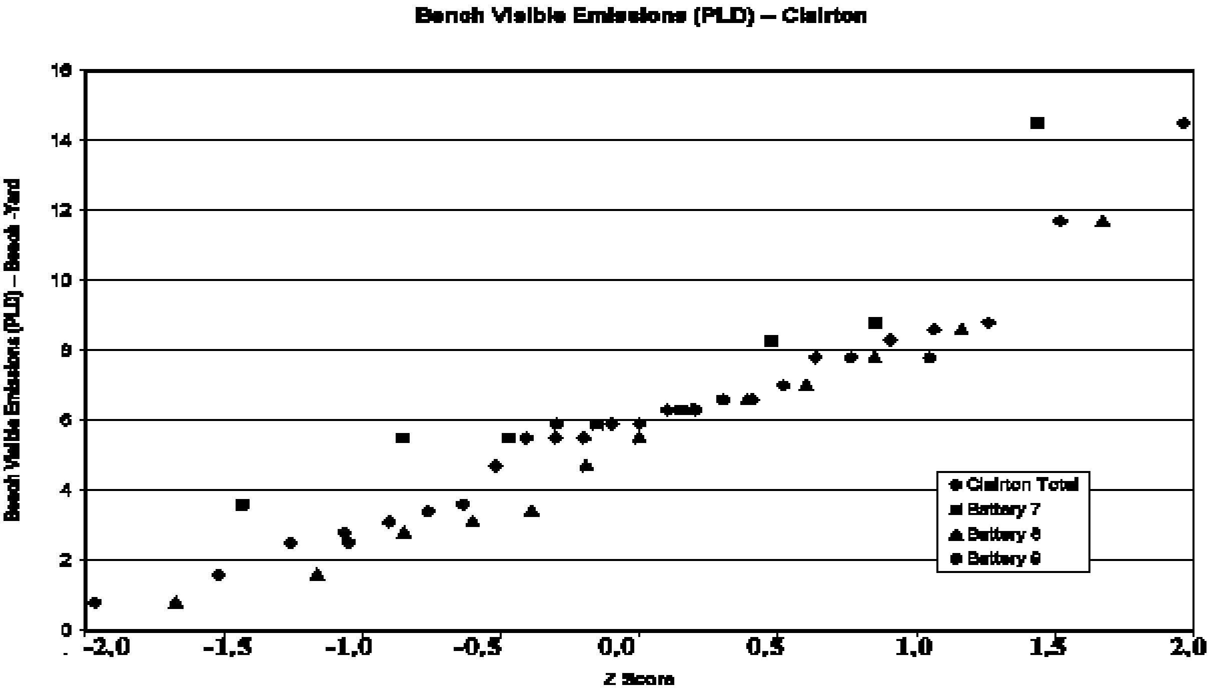
2.4.5 Emission Rates from Non-Visible Leaking Doors (ERnv)

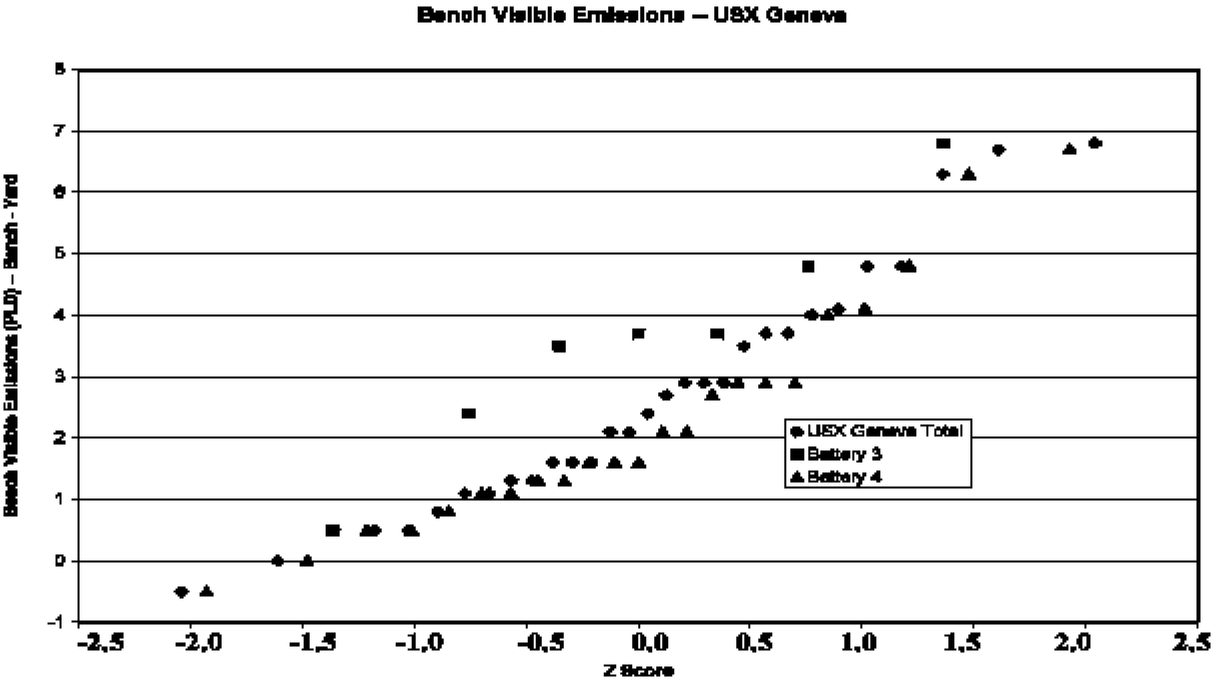
Data suggest that emissions may exist even when there are no visible emissions seen from the bench, (i.e., from the closest viewable position). Table 2-6 indicates that limited evidence exists to show that emissions may be occurring from doors which do not appear to be leaking either from the yard or the bench (leak Category of 0). A total of 4 data points are available from the testing for emissions from empty and non-visibly leaking doors. These data yield a mean of 0.0046 and a standard deviation of 0.0023. These four data points were evaluated using a z-score regression technique which indicated that the data could be described preferentially by a normal distribution (R^2 = 0.986) rather than a lognormal distribution (R^2 = 0.966). Since it is not feasible for negative emissions to occur from such ovens, a normal distribution with a mean of 0.0046 and a standard deviation of 0.0023 truncated at zero was used.

2.4.6 Emission Rates from Leaking Lids and Offtakes (ERllo)

ELO = PLLO * ERllo
ELO = Emissions from leaking lids and offtakes = lb/hr/lids and offtakes
PLLO = Percent leaking lids and offtakes = PLL + PLO
PLL = Percent leaking lids
PLO = Percent leaking offtakes
Erllo = Emission rate for leaking lids and offtakes

Figure 2-9. Comparison of Bench-only Visible Leaking Doors Across Batteries


Bench Visible Emissions (PLD) – Clairton


Bench Visible Emissions – USX Geneva

The MACT defines specific allowable limits for percent leaking lids and offtakes, six and three percent, respectively. Therefore, only the emission rate for leaking lids and offtakes were evaluated for uncertainty.

A total of three tests were made to measure the emissions from topside leaks. It is assumed that the rate from lids and offtakes would be equal. The measured BSO emission rates were 0.0037, 0.0064, and 0.12 lb/hr in these test runs. Using a z-score regression approach indicated that these three data points could be reasonably described by a lognormal distribution. Therefore, a lognormal distribution described by the observed mean (0.0074) and standard deviation (0.0042) were used to describe the uncertainty in ELO.

2.4.7 Results of Uncertainty Analysis

Stochastic (Monte Carlo) simulation was used to determine the uncertainty in the emissions estimates based on the uncertainty and variability within each of the parameters used in the emissions model. The probability distributions described above for each of the parameters were used in the simulation.

The stochastic simulation was repeated a total of 1,000 times to produce a frequency distribution of calculated BSO emission values. Running the simulation 1,000 times was selected based on observations that the forecast curve was smooth. A quick review of data from 2,000, 3,000, 4,000, and 5,000 simulations showed little change in resulting statistics and percentiles between 1,000 and the other iterations.

2.4.7.1 BSO Emissions Without Non-visible Leaking Doors

Table 2-8 summarizes the distributions used for each of the parameter inputs. Table 2-6 summarizes the simulated distribution of predicted BSO emissions from doors and total for AK Ashland, AK Middletown, Erie and Tonawanda, while Figure 2-10 graphically presents the distributions predicted. This distribution gives some indication of the degree of uncertainty and the possible range of emissions estimates that may be experienced.

The original emissions estimation protocol had been designed to provide an unbiased estimation of emissions. The results of the uncertainty analysis tend to support this assertion. The original baseline estimates fell within the 50-75th percentile range of the overall distribution. The mean of the distribution was typically less than the point estimate (the MACT allowable limit). Furthermore, the 95th percentile of the simulated range of long-term average emissions estimates are within a factor of two of the original baseline estimate and the mean of the simulation.

Table 2-6. Summary of Simulated Distribution of BSO Emissions (tons/yr) Uncertainty without Non-Visible Leaking Doors

	AK Ashland		AK Middletown		Erie Coke		Tonawanda	
Percentile	Doors	Total	Doors	Total	Doors	Total	Doors	Total
0.0%	0.4	0.6	0.2	0.3	0.2	0.2	0.2	0.2
2.5%	1.1	1.3	0.6	0.7	0.4	0.5	0.4	0.5
5.0%	1.3	1.5	0.7	0.9	0.5	0.6	0.5	0.6
10%	1.6	1.8	0.8	1.0	0.6	0.7	0.6	0.7
25%	2.3	2.5	1.2	1.4	0.9	1.0	0.9	1.0
50%	3.3	3.6	1.7	1.9	1.3	1.4	1.4	1.5
75%	4.6	4.9	2.4	2.6	1.8	1.9	1.9	2.0
90%	6.3	6.6	3.3	3.5	2.5	2.6	2.6	2.7
95.0%	7.8	8.0	4.1	4.2	3.1	3.2	3.2	3.3
97.5%	9.3	9.6	4.9	5.0	3.7	3.8	3.8	3.9
100.0%	19.6	19.9	10.2	10.4	7.8	7.9	8.0	8.1
Mean	3.8	4.1	2.0	2.2	1.5	1.6	1.6	1.7
Point	4.0	4.7	2.3	2.6	1.7	1.9	1.8	2.0

2.4.7.2 Emissions With Non-Visible Leaking Doors

As mentioned earlier, there are data which indicate that emissions may be occurring even from doors which do not appear to be leaking. Table 2-7 summarizes the distribution of predicted emissions including the non-visible leaks for AK Ashland, AK Middletown, Erie and Tonawanda, while Figure 2-11 graphically presents the distributions predicted . This distribution gives some indication of the degree of uncertainty and the possible range of emissions estimates that may be experienced. When non-visible leak emissions are included in the emissions estimate, the baseline MACT emissions estimate appears to be biased toward underestimating emissions. The addition of the non-visible leaking doors, in general doubles the overall emissions estimate. The original emission estimate now falls within the 5-10 percentile range of the overall distribution. The 95th percentile of the simulated range of long-term average emission estimates are within a factor of about 3 of the original baseline MACT estimate.

Table 2-7. Summary of Simulated Distribution of BSO Emissions (tons/yr) Uncertainty with Non-Visible Leaking Doors

	AK Ashland		AK Middletown		Erie Coke		Tonawanda	
Percentile	**Doors**	**Total**	**Doors**	**Total**	**Doors**	**Total**	**Doors**	**Total**
0.0%	1.8	2.1	0.9	1.2	0.7	0.8	0.7	0.9
2.5%	3.3	3.4	1.7	1.8	1.3	1.3	1.3	1.4
5.0%	4.0	4.3	2.1	2.3	1.6	1.7	1.6	1.8
10%	5.0	5.2	2.6	2.7	2.0	2.1	2.0	2.1
25%	6.8	7.0	3.5	3.7	2.7	2.8	2.8	2.9
50%	8.9	9.2	4.6	4.8	3.5	3.7	3.7	3.8
75%	11.1	11.4	5.8	6.0	4.4	4.5	4.6	4.7
90%	13.5	13.8	7.0	7.2	5.4	5.5	5.6	5.6
95.0%	15.0	15.2	7.8	8.0	5.9	6.0	6.1	6.2
97.5%	16.3	16.6	8.5	8.7	6.5	6.6	6.7	6.8
100.0%	26.7	26.9	13.9	14.0	10.6	10.7	11.0	11.0
Mean	9.1	9.4	4.7	4.9	3.6	3.7	3.7	3.8
Point	4.0	4.7	2.3	2.6	1.7	1.9	1.8	2.0

2.4.8 Discussion

The focus of this uncertainty analysis was on the emissions estimation protocol which was intended to produce unbiased estimates of BSO emissions. This analysis focused on emissions because of their uniqueness to this source category not because they are the greatest source of uncertainty in this risk assessment. Several risk assessments of coke ovens have been carried out over the past several years, and the major differences between this current assessment and previous ones include the revised emissions estimates and the inclusion of thermal plume rise into the dispersion modeling.

Other components of risk assessments, (e.g., dispersion modeling, dose-response or potency factors) have had uncertainty analyses in previous assessments of other source categories. For example, an uncertainty analysis was carried out for the electric utility source category in support of the Utility Report to Congress (US EPA, 1998b). In this scenario-based approach, the focus was on dispersion and exposure modeling. Specific parameters for dispersion included stack parameters, stack gas temperatures, and exit velocities while uncertainty about the mean (or best estimate for a given parameter within the exposed population) included exposure frequency, exposure duration, breathing rate, deposition fraction, and retention half-times. The results of the utility uncertainty analysis indicated that the baseline deterministic risk assessment results were conservative estimates of risk which are more likely to overestimate than underestimate risk. The deterministic estimates of risk ranged from the 71st percentile to the 98th percentile when compared to the probabilistic results. The 95th percentile (a typical high-end risk estimate) of the overall distribution was found to be roughly twice the original deterministic risk estimate, or about five times the mean.

The results of the uncertainty analysis discussed in this report support the protocol used to generate unbiased estimates of BSO emissions if emissions from non-visibly leaking doors are not included. In that scenario, the simulation yielded mean estimates approximating the original BSO emission estimate. Further, the 95th percentile of the simulated values was within a factor of 2 of the original estimate. If emissions from non-visibly leaking doors are considered, emissions can be expected to increase by a factor of 2 on average, and with the resulting 95th percentile of the emissions distribution being about a factor of 3 higher than the original estimate. It should be noted that the uncertainty estimates presented in this report are likely to underestimate the true overall emissions variability and uncertainty for several reasons.

The approach used, (i.e., focusing on parameter uncertainty), did not address all parameters related to plant emissions. Evidence also indicates that commonly used 95% bounds for normal and lognormal distributions of variables are very sensitive to the underestimation of the true uncertainty and typically do not address unsuspected errors which are quite common. Also, new measurements are often far from the previous values because environmental measurements are rarely repeated with the same samples, and it is hard to estimate how widespread the unaccounted errors are in routinely collected data. EPA recognizes the potential for unsuspected errors in the data and its associated representation of uncertainty. The manner in which the data were collected and reported may contribute to these errors. For example, during testing of door leaks, it was observed that condensation of aerosol emissions occurred on the shroud and could not be avoided. As a result, these condensed emissions were not measured, resulting in a potential bias toward underestimating total emissions. Data are often collected under relatively favorable conditions in these respects and, therefore, may not entirely reflect the full variability of important operating parameters that would be seen over the lifetime of these facilities (Hattis and Burmaster, 1994).

EPA risk assessments are generally conservative (more likely to overestimate than underestimate) risks. This conservativeness is usually appropriate given EPA's mandate of public health protection. Often there is concern that the use of conservative assumptions result in risk estimates which are unrealistic and beyond the range of possible risks. The results of this uncertainty analysis which focused on the emissions plus the characterization of uncertainty from other analyses indicate that the deterministic risk estimates, (i.e., the estimates of risk shown in Table 3-10), are reasonably conservative and within the range of plausible risks. The uncertainty analysis presented here supports the original emission estimates, suggesting that, while actual emissions may be higher, they are unlikely to exceed the values used in this assessment by a factor of 3.

Under different circumstances, it would be desirable to have a more complete treatment of uncertainty. However, given the resource requirements for such an analysis and the potential impact on informing the regulatory decision we do not feel it was warranted in this case. We have asserted that the uncertainty analysis is commensurate with the type of decision supported. Regulatory decisions within the residual risk program are tied to two specific risk levels, one defining unacceptability (an excess lifetime cancer risk of 100 in a million or 10^{-4}) and one defining a level at which risk reduction is no longer warranted (an excess lifetime cancer risk of 1 in a million or 10^{-6}). If risks are between these two levels, then the appropriate regulatory decision is not based on risk alone, but must also consider costs, technical feasibility, economics and other considerations. Keeping in mind these risk levels, the uncertainty analysis described here indicates that the maximum individual risks, while possibly higher, are likely to be below the unacceptable risk level of 100 in a million, and that there is very small likelihood that the maximum individual risk would be below the 1 in a million level. Therefore, the regulatory decision would not tend to be made based on risk alone, and other considerations such as technical feasibility in this case would tend to drive the decision. For other source categories where risk may play a more critical role or where other considerations (such as technical feasibility) do not clearly dominate, then a more detailed uncertainty analysis would certainly be warranted to better inform the decision. However, while desirable, a more detailed uncertainty analysis for this source category would not be expected to impact or better inform the decision.

Table 2-8. Input Parameter Distributions for Uncertainty Analysis of Emissions

Parameter	**Assumptions**				
	Emission Rate for Yard Visible Door Leaks (lbs.hr)[1]	Emission Rate from Non-visible Leaking Doors (lbs/hr)[2]	Emission Rate from Leaking Lids and Offtakes (lbs/hr)[3]	Percent Leaking Doors Visible from Bench[4]	Emission Rate for Bench Visible Door Leaks (lbs/hr)[5]
Distribution	Lognormal	Normal	Lognormal	Normal	Lognormal
Geometric Mean	0.03				0.02
Geometric Standard Deviation	2.05				1.7
Mean		0.0043	0.0074	4.3	
Standard Deviation		0.0023	0.0042	2.2	

Selected range for all is from 0.0 to infinity.

[1] Mean value in simulation was 0.04.

[2] Mean value in simulation was 0.00.

[3] Mean value in simulation was 0.01.

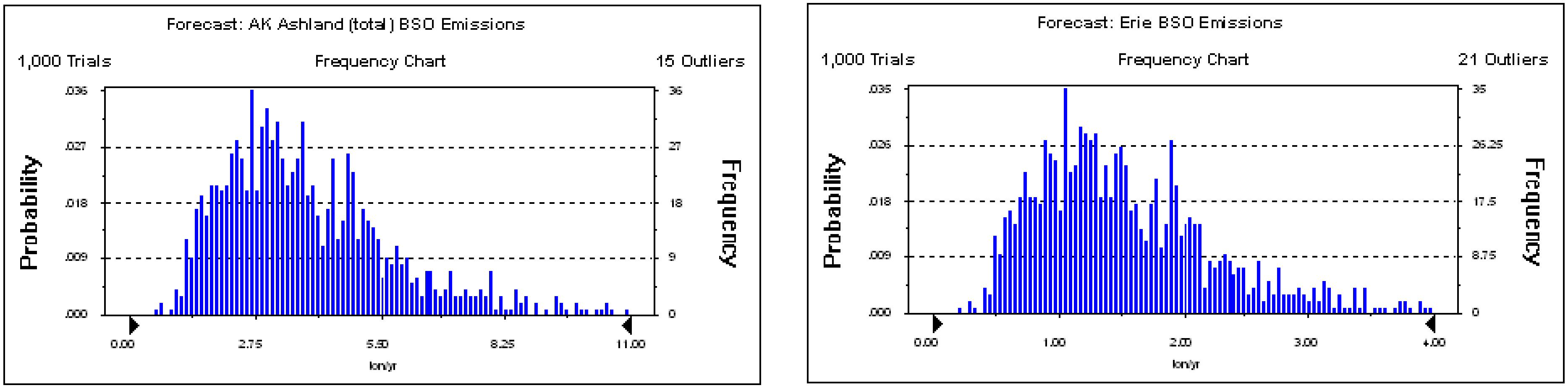
[4] Mean value in simulation was 0.043.

[5] Mean value in simulation was 0.03.

Figure 2-10. Simulated BSO Emissions (tons/yr) Without Non-visible Leaking Doors

Forecast: AK Ashland (total) BSO Emissions

Forecast: Erie BSO Emissions



Forecast: AK Middleton BSO Emissions

Forecast: Tonawanda BSO Emissions

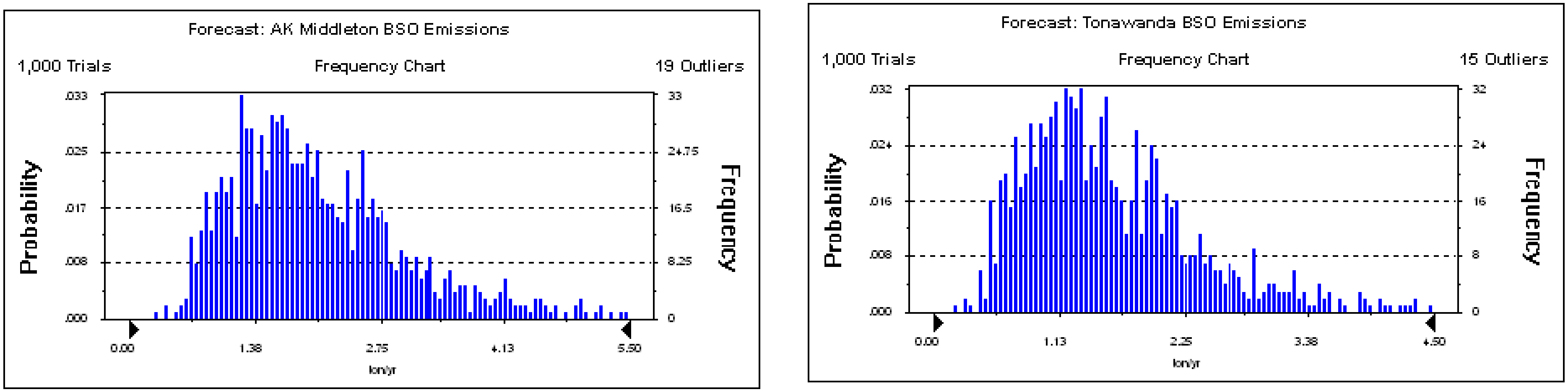
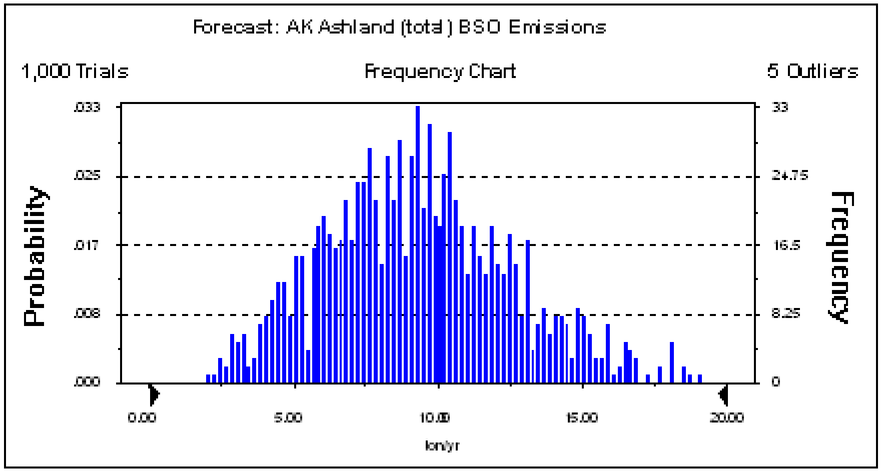
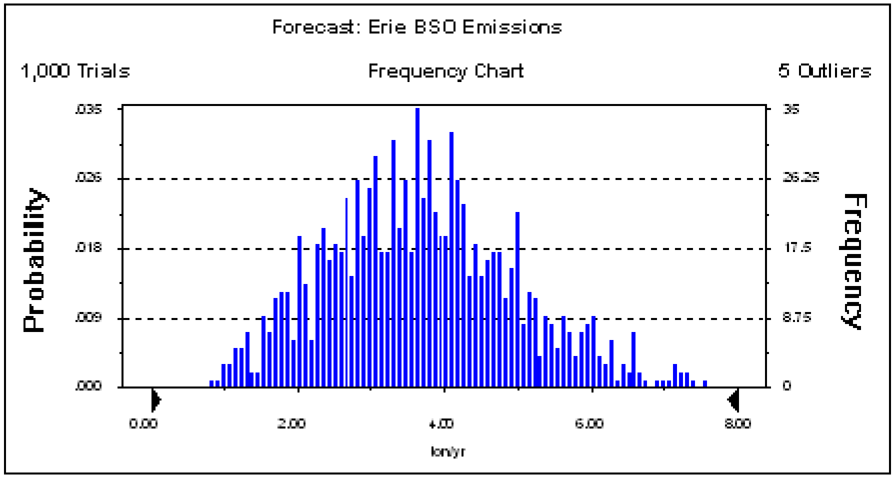


Figure 2-11. Simulated Emissions (tons/yr) with Non-visible Leaking Doors

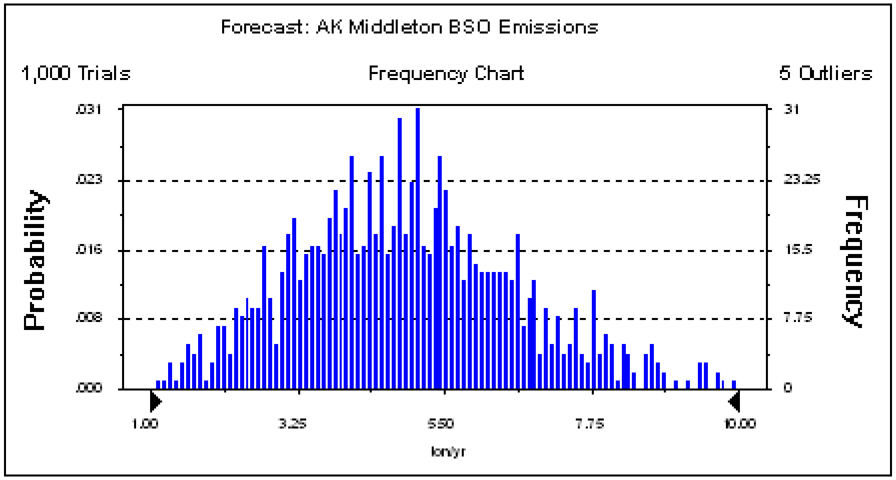
Forecast: AK Ashland (total) BSO Emissions



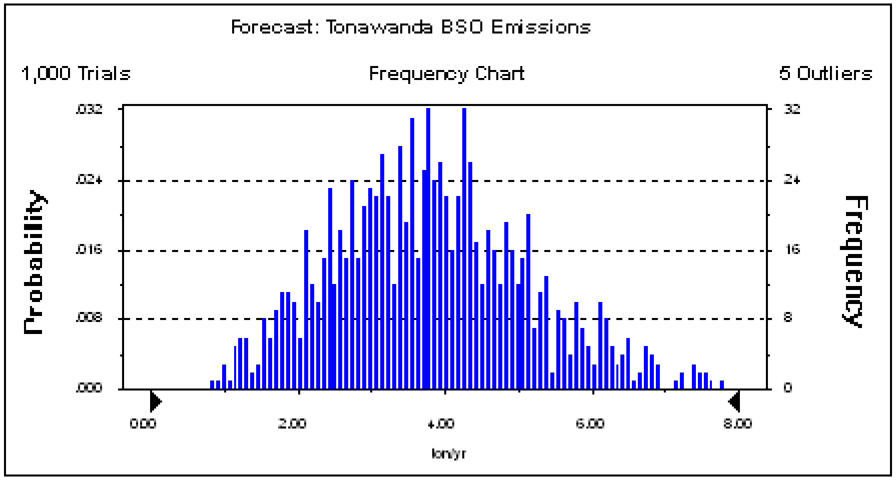
Forecast: Erie BSO Emissions



Forecast: AK Middleton BSO Emissions



Forecast: Tonawanda BSO Emissions



2.4.9 Qualitative Uncertainty

Lack of data and the constraints of available models invariably introduce uncertainty into a risk assessment. Assumptions must be made to accommodate data gaps and limitations in available assessment methodologies. In some cases, the degree of uncertainty introduced can be quantified, (i.e., the emission estimates described above) while in other cases qualitative treatments must suffice.

In discussing or describing uncertainty qualitatively, the discussion should include what effect a particular parameter has on bias. Possible variations may be that an analysis component or assumption is unbiased and, therefore, equally likely to over- or under-estimate risk, while other parameters may push an outcome in a particular direction, (i.e., the bias is to under- or over-estimate risk but not with equal likelihood). An equally important consideration has to be made for what magnitude of impact the potential bias may have on a specific analysis result. For example, this assessment makes the assumption that the population living around these facilities will remain the same as that identified in the 2000 Census. If a qualitative estimate of bias were to be made, it could be that this assumption has no bias and would be considered "representative" of that parameter, the population around these facilities. As Table 2-9 shows, there was an increase in the population within 50 km for 3 of these facilities between 1990 and 2000 while the population near the 4th facility decreased. Therefore, our assumption of a stable population may under-estimate population risk for future years for 3 of these facilities, but over-estimate for the 4th. However, from a quantitative point of view, the impact or magnitude of this potential bias may be too small to actually be of concern. Other than the emissions uncertainty analysis described above, no additional attempt was made to describe other parameters quantitatively. The information in Table 2-10 is an attempt to provide some sense of the qualitative "bias" of selected parameters in this assessment.

Table 2-9. Comparison of 1990 and 2000 Population Data for 50-Kilometer Study Areas

Census Data	AK Steel Middletown	AK Steel Ashland	Erie Coke	Tonawanda
2000	2,327,420	397,947	333,159	1,163,322
1990	2,235,046	384,729	315,870	1,176,952
Difference	**92,374**	**13,218**	**17,289**	**-13,630**

Table 2-10. Qualitative Uncertainty Bias Table

Parameter	Default Option / Assumption	Data (e.g., source quality)	Uncertainty/Variability/ Bias
Emissions Characterization (see quantitative evaluation of uncertainty of various emissions factors)			
Temporal	Emissions are assumed to be continuous. While the coke oven process is a batch process on an oven basis, there are many ovens per battery which are in various stages of continuous operation. The assumption here is that emissions are continuous.	Continuous operation of batteries is well documented.	Believed to be unbiased with respect to long-term annual average concentrations. There may be some bias toward under-estimating peak short-term concentrations if the release from a specific oven near receptors coincide with acute meteorology to impact that receptor. The degree of under-estimating is dependent on the degree to which oven emissions are discrete or captured within the overall buoyant plume.
Dispersion and Exposure Modeling			
Dispersion	Gaussian plume		Believed to be unbiased and good approximation for long-term average concentrations (within a factor of 2 to 3)
Building Downwash			The batteries assessed are typically 7 meters high. We have estimated the representative stack heights of between 30 and 70 meters (on average). It is not likely that factors such as building downwash, would alter the volume of emissions in this buoyant plume

Table 2-10. Qualitative Uncertainty Bias Table

Parameter	Default Option / Assumption	Data (e.g., source quality)	Uncertainty/Variability/ Bias
Plume Rise / Effective Stack Height	ISC does not adequately handle the buoyant plume rise believed to be encountered at such high-temperature emission sources such as coke oven batteries. Therefore, to account for the thermal lift of the plume, the Buoyant Plume Rise (BLP) Model was used to estimate the plume rise for the meteorological conditions at each site using specific plant data to calculate buoyancy flux. The calculated plume rise was then input into ISC as an effective plume height. This was done in "real-time" to reflect the meteorological conditions encountered.	Meteorological date for a 5 year period was used to estimate the impact of buoyant plume rise and the effective plume height. Data based on 5 years of data at nearest meteorological station was equivalent to that used in the dispersion modeling. Facility specific data used to calculate buoyancy flux.	Believed to be unbiased and reasonably accurate description of actual processes. Gradual plume rise (and concomitant initial dispersion) was not included in assessment. As a result, ground-level concentrations near the source may be underestimated. However, the impact of this assumption is most important for near-ground level releases and as the effective plume heights in this case are large the impact is not expected to be significant.
Roughness (urban v. rural dispersion curves)	Population density (within 3 km of facility) is assumed to be an indicator or proxy for setting of the plant, and that urban and rural are representative of surface roughness. Binary choice of urban v. rural.	Census data on population within 3 km of facility.	Roughness not binary and not always attributable to population density (e.g., buildings) but other land features as well. Urban and rural model default settings may not represent the entire range of surface roughness leading to possible extremes not addressed. However, given the large effective plume heights, the impact of this parameter may be reduced.
Terrain	Assumed to be in simple terrain. Simple terrain (terrain below plume height) used in gaussian plume dispersion.	USGS digital elevation maps available for facilities if needed.	Terrain effects can be significant where the terrain features exceed the effective stack height leading to minimal dispersion and high exposure. However given the large effective plume heights the impact of this parameter is not anticipated to be significant for these facilities.

Table 2-10. Qualitative Uncertainty Bias Table

Parameter	Default Option / Assumption	Data (e.g., source quality)	Uncertainty/Variability/ Bias
Meteorology	The meteorological data from the nearest location are used to represent the meteorology near the plant.	These data are running five-year averages.	Intended to be an unbiased best estimate. Meteorology at site may be significantly different than the nearest site. Met conditions at site will vary over time, using five years of met data are believed to capture most meteorological variability
Stack Height	Release height for battery emissions is assumed to be the height of battery. Release points for other releases such as combustion stack and By-product recovery plant are known	Height of each battery is known for each facility.	The analysis is believed to have neutral bias and not likely to lead to over- or under-estimates
Maximum Modeling Distance	50 kilometers	EPA modeling community	This distance has become the standard dispersion modeling distance for EPA and is considered the standard maximum downwind distance for ISC. Beyond this, other models, (e.g., regional transport models) are more appropriate. Variations in modeling distance are not expected to affect the location of the maximum air concentrations, (i.e., in all cases, for ambient conc. and deposition rates), the maximum impacts are bracketed by the receptors within the 50km distance, and because the focus of this assessment is on the maximum individual risk, it shouldn't be affected by modeling distance). Incidence calculations might be. This parameter is therefore, considered unbiased.

Table 2-10. Qualitative Uncertainty Bias Table

Parameter	Default Option / Assumption	Data (e.g., source quality)	Uncertainty/Variability/ Bias
Reactivity of pollutants	Chemical reactivity of pollutants was not modeled as part of the dispersion modeling.	Limited data on individual chemicals emitted and their reactivity	Unknown bias. Depending on which chemicals emitted are subject to transformation and the relative toxicity of the transformed product compared to the original pollutant, the risks may be higher or lower than estimated.
Deposition	Wet and dry deposition was addressed using ranges of particle sizes. Plume depletion was not addressed.	Particle size data from coke pushing operations (AP-42 document) was source. The Human Health Risk Assessment Protocol (HRAP) equations used to estimate fraction.	Unknown bias. BSO emissions are used as a surrogate of coke oven emissions. The components of coke oven emissions include particulate matter which is anticipated to settle out more than volatile or gaseous components, and the composition will change. Therefore, the risks may be either under-estimated or over-estimated based on the relative toxicity of those which settle versus those which remain airborne.
Exposure Assessment			
Exposure Concentration	The long-term average ambient concentration at the residence location is representative of a person long-term average exposure due to: – person spends most of their time at home – in the absence of data to the contrary, long-term average indoor concentration are assumed to be equivalent to ambient levels – human activity patterns and mobility not explicitly accounted for	Modeled average ambient concentration using ISCST3	Intended to be marginally health protective. Exposures may be lower than predicted because indoor levels may be less than ambient. While marginally lower for some it may be significant for others. Exposures may be higher or lower than estimated when human activity patterns (e.g., commuting) are considered as people may be moving to either higher or lower concentrations than found at their residence location (1996 NATA found minimum impact when activity patterns considered)

Table 2-10. Qualitative Uncertainty Bias Table

Parameter	Default Option / Assumption	Data (e.g., source quality)	Uncertainty/Variability/ Bias
Receptor Location	Population is assumed to be uniformly distributed within habitable land use areas within a census block	US Census 2000	Intended to be unbiased. Actual exposures would be higher or lower as concentrations spatially vary within the census block. Since census blocks are relatively small, this variation is not expected to be great.
Exposure Frequency	Assumed to be 365 days per year		Intended to be health protective, and therefore, more likely to overestimate than underestimate. While most people do not remain at home or near their homes for an entire day, many individuals do and this approach is protective of them.
Exposure Duration	For cancer risk assessment, it is assumed that people reside in one location for their entire lifetime of 70 years.	Average lifespan EPA Exposure Factors Handbook (based on residency surveys)	Intended to be reasonable assessment which is health protective, and therefore, more likely to overestimate than underestimate. While most people, (i.e., the general population) may not live in one location for their entire life, many individuals do and this approach is protective of them. Probabilistic modeling of exposure duration has a bias toward underestimating exposure. The typical assumption is that once people move they are no longer exposed. Residency survey data do not adequately capture the chance that people will move in the vicinity (still within the impacted area of the source) immediately or over lifetime.
Exposure-Response Assessment			

Table 2-10. Qualitative Uncertainty Bias Table

Parameter	Default Option / Assumption	Data (e.g., source quality)	Uncertainty/Variability/ Bias
Exposure-Response Surrogate	Benzene Soluble Organics (BSO) are assumed to be representative of the exposure-response in the exposed population. While BSO does not measure all components of coke oven emissions, it is a surrogate for coke oven emissions including non-BSO components.	Human epidemiological studies used BSO as a surrogate for (worker) exposure and response. Limited data on components of BSO which is not likely exclusive and do not include non-BSO components of coke oven emissions.	Intended to be unbiased. It is likely that the makeup of coke oven emissions to which people are exposed in the community differs from that of workers onsite due to deposition and/or transformation of individual constituents. Such change in makeup could result in higher or lower toxicity potential depending on which constituents and their toxicity are altered.
Unit Risk Estimate	Coke oven emissions as measured in epidemiological studies are a surrogate for dose-response, and are applicable to offsite exposures as well.	Human epidemiological data for Coke Oven Emissions	URE is intended to be health protective, (i.e., more likely to be overestimated than underestimated). While the actual potency may be higher, it is more likely to be lower.

The information above tries to provide some indication of whether this assessment may overestimate or underestimate the risks or hazards presented. It is generally assumed that risk assessments such as this do overestimate risks because of the inherent bias of some parameters included in risk assessments, (e.g., health values currently used), but some balancing of this may occur when high-quality, site-specific data is substituted for default assumptions. This risk assessment for the 4 coke oven facilities has utilized high-quality data with minimum defaults, providing that balance to those variables we have little or no control over.

As required by the decision framework of the Clean Air Act, this assessment appropriately focuses on estimating the risks that a person living near one of these facilities would have if they were exposed to the maximum HAP concentrations over a lifetime of 70 years. Within the construct of such an exposure scenario and the fact that good, site-specific data were used, we believe that this assessment is, overall, an unbiased assessment (even within an order of magnitude variation) of the risks and hazards to that individual we are charged to protect.

3.0 Analysis Results

As described in the *Residual Risk Report to Congress*, this assessment was performed iteratively and follows the diagram in the beginning of Section 2 (Figure 2-1). Initial iterations were screening-level assessments designed to help narrowing the scope of a refined analysis. There were 3 screening-level assessments done; a human inhalation, multipathway, and an ecological assessment. These are described in more detail below.

3.1 Inhalation Screening Assessment

The initial step in the inhalation screen was to establish the universe of HAPs that are constituents of the HAP, "coke oven emissions". Appendix C provides extensive information on coke oven emissions from the various coke oven sources. Using the established heirarchy of sources of toxicity benchmarks, the benchmarks available were identified (see Appendix B, Table B-1). The presence of both emissions and toxicity benchmarks were then used to select the HAP constituents to be assessed in this screening assessment (see Table 3-1).

The outcome of this assessment estimated risks or health hazards that would occur if it were assumed that the maximum air concentrations from all emission sources for each facility occurred at the same location. In actuality, because of differences in position, orientation, and air dispersion characteristics, the maximum air concentrations for each source are likely to occur at different locations, and it would be anticipated that no receptor would be exposed to concentrations that were higher than what is estimated in the screening assessment. For a screening level assessment, this assumption is appropriate because it is health protective and allows us to narrow the scope of the refined level assessment with more confidence. In a comparison of the screening and refined results, it would be expected that any predicted risks or health hazards estimated in the refined assessment discussed later in this report, would be lower.

Steps in Inhalation Screening Assessment

- Establish universe of coke emission constituents
- Compile toxicity values (Appendix B, Table B-1)
- Select HAP constituents to be included in screen based on availability of emissions and toxicity values
- Calculate risk and hazard quotient for each HAP (Appendix A, Tables A-2 to A-9)
- Calculate overall estimated risk and health hazard for each coke plant by summing risks and noncancer HQ's (regardless of target organ) across all emission sources (Tables 3-2 and 3-3)
- Determine which facilities, emission sources, or HAPs would be considered in more refined

Table 3-1. Constituents Included in Inhalation Screening Analysis

CAS	Constituent
99992	Benzene soluble organics
91203	Naphthalene
7440382	Arsenic
7782492	Selenium
71432	Benzene
74908	Hydrocyanic acid
108883	Toluene
1330207	Xylene (mixed isomers)
75150	Carbon disulfide
108952	Phenol
106445	Cresol, p-
95487	Cresol, o-
98828	Cumene
106990	Butadiene
7647010	Hydrochloric acid (HCL)
7664393	Hydrofluoric acid (HF)
7439921	Lead
7440020	Nickel
7439965	Manganese
7440439	Cadmium
7440417	Beryllium
7440484	Cobalt
7440360	Antimony
50328	Benzo(a)pyrene
218019	Chrysene
56553	Benzo(a)anthracene
207089	Benzo(k)fluoranthene
205992	Benzo(b)fluoranthene
7723140	Phosphorus

A summary of these results are shown in Table 3-2 and Table 3-3 which present the non-cancer and cancer results, respectively. More detailed presentation of the results may be found in Appendix A., Tables A-2 to A-9.

Table 3-2. Summary of Noncancer Risk Assessment Screening Analysis[**]

Constituent	AK Steel Middletown	AK Steel Ashland	Erie Coke	Tonawanda
Benzene	$6x10^{-2}$	2	$4x10^{-2}$	$2x10^{-1}$
Hydrocyanic acid	$6x10^{-4}$	$7x10^{-3}$	$2x10^{-3}$	$1x10^{-3}$
Carbon disulfide	$5x10^{-8}$	$6x10^{-7}$	$2x10^{-7}$	$1x10^{-7}$
Naphthalene	$2x10^{-3}$	$3x10^{-2}$	$7x10^{-3}$	$4x10^{-3}$
Cresol, o-	$4x10^{-9}$	$5x10^{-8}$	$2x10^{-8}$	$1x10^{-8}$
Cumene	$3x10^{-7}$	$3x10^{-6}$	$1x10^{-6}$	$6x10^{-7}$
Cresol, p-	$1x10^{-8}$	$1x10^{-7}$	$5x10^{-8}$	$3x10^{-8}$
1,3- Butadiene	$2x10^{-5}$	$2x10^{-4}$	$7x10^{-5}$	$4x10^{-5}$
Toluene	$3x10^{-4}$	$1x10^{-2}$	$2x10^{-4}$	$1x10^{-3}$
Phenol	$1x10^{-7}$	$1x10^{-6}$	$4x10^{-7}$	$3x10^{-7}$
Xylene (mixed)	$1x10^{-4}$	$5x10^{-3}$	$6x10^{-5}$	$4x10^{-4}$
Lead	$5x10^{-4}$	$9x10^{-3}$	$1x10^{-3}$	$1x10^{-3}$
Manganese	$5x10^{-3}$	$9x10^{-2}$	$1x10^{-2}$	$1x10^{-2}$
Mercury	$1x10^{-5}$	$2x10^{-4}$	$3x10^{-5}$	$2x10^{-5}$
Nickel	$2x10^{-3}$	$4x10^{-2}$	$6x10^{-3}$	$5x10^{-3}$
Antimony	$1x10^{-4}$	$2x10^{-3}$	$3x10^{-4}$	$2x10^{-4}$
Arsenic	$1x10^{-2}$	$3x10^{-1}$	$4x10^{-2}$	$3x10^{-2}$
Beryllium	$3x10^{-4}$	$5x10^{-3}$	$8x10^{-4}$	$6x10^{-4}$
Cadmium	$1x10^{-3}$	$2x10^{-2}$	$3x10^{-3}$	$3x10^{-3}$
Cobalt	$2x10^{-4}$	$4x10^{-3}$	$6x10^{-4}$	$4x10^{-4}$
Hydrochloric acid	$2x10^{-6}$	$2x10^{-5}$	$7x10^{-6}$	$4x10^{-6}$
Hydrofluoric acid	$6x10^{-9}$	$7x10^{-8}$	$2x10^{-8}$	$1x10^{-8}$
Phosphorus	$2x10^{-3}$	$4x10^{-2}$	$3x10^{-3}$	$5x10^{-4}$
Selenium	$5x10^{-6}$	$9x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$
Total	**$8x10^{-2}$**	**3**	**$1x10^{-1}$**	**$3x10^{-1}$**

[**] Each row of this table represents a facility level hazard quotient, (e.g., the sum of hazard quotients from all sources of benzene). The "Total" row represents the hazard indices (HI) for each facility, (i.e., the sum of each facility- level hazard quotient for all HAPs modeled at that facility. For the screening level assessment, these HI do not consider target organs.

3.1.1 Selection Criteria Screening Assessment Decisions

The following criteria were applied to the inhalation screening results in order to help prioritize which components, (i.e., HAPs, emission sources, or facilities), would need further analysis. For a facility or constituent to screen out, it had to meet the criteria at each facility. The selection criteria were:

- Facility or constituent cumulative, estimated cancer risk is < 1 in a million ($<1x10^{-6}$),
- The constituent contributes less than 1% to total facility risk, and
- The facility or constituent has an HQ limit ≤ 0.2 or HI limit ≤ 0.2 (not target organ specific)

Table 3-3. Summary of Cancer Risk Assessment Screening Analysis

Constituent	AK Steel Middletown	AK Steel Ashland	Erie Coke	Tonawanda
Benzo(a)pyrene	$2x10^{-10}$	$4x10^{-9}$	$2x10^{-10}$	$2x10^{-10}$
Benzo(a)anthracene	$2x10^{-10}$	$4x10^{-9}$	$3x10^{-10}$	$2x10^{-11}$
Benzene	$2x10^{-5}$	$5x10^{-4}$	$7x10^{-6}$	$5x10^{-5}$
Benzene soluble organics	$5x10^{-5}$	$8x10^{-4}$	$2x10^{-4}$	$1x10^{-4}$
Benzo(b)fluoranthene	$2x10^{-10}$	$4x10^{-9}$	$2x10^{-10}$	$4x10^{-11}$
Benzo(k)fluoranthene	$1x10^{-10}$	$2x10^{-9}$	$2x10^{-10}$	$2x10^{-13}$
Chrysene	$6x10^{-11}$	$1x10^{-9}$	$7x10^{-11}$	$6x10^{-12}$
Nickel	$2x10^{-9}$	$4x10^{-8}$	$3x10^{-9}$	$6x10^{-10}$
Arsenic	$3x10^{-8}$	$6x10^{-7}$	$3x10^{-8}$	$2x10^{-8}$
Beryllium	$5x10^{-10}$	$1x10^{-8}$	$6x10^{-10}$	$1x10^{-10}$
Cadmium	$2x10^{-9}$	$4x10^{-8}$	$2x10^{-9}$	$9x10^{-10}$
Total	**$7x10^{-5}$**	**$1x10^{-3}$**	**$2x10^{-4}$**	**$2x10^{-4}$**

All facilities had estimated, lifetime, cancer risks greater than 1 in a million ($>1 \text{ x } 10^{-6}$). The majority of this risk is driven by benzene and coke oven emissions (as BSO). Two facilities, AK-Steel Ashland and Tonawanda had individual HQs that exceeded the criteria. These HQs were for benzene and arsenic. Erie Coke's total HI exceeded the criteria with benzene and arsenic being the drivers for that total HI.

3.2 Multipathway Exposure Screening Assessment

We also conducted a multipathway exposure screening analysis to further refine the number of

Initial Steps in Multipathway Exposure Screening Assessment

- Consider universe of coke oven emission HAPs
- Select HAPs of concern for PBT
- Determine the emissions of HAPs selected

HAPs and routes of exposure that would be considered in the more refined level assessment. The steps in this screen are described in the text box.

First we determined which HAPs from the universe of constituents (see Table A-1) of coke oven emissions are most likely to be of concern for non-inhalation exposures. This was done by comparing the constituent HAP with the EPA *Draft Prioritization Chemical List* (U.S.EPA, 1997a). This list represents a relative ranking of 879 chemicals based on their persistence, bioaccumulation potential, and toxicity (PBT) as predicted by the *Waste Minimization Prioritization Tool (WMPT)*. The WMPT is a screening tool that is intended to provide a sense of the relative concern for a particular chemical in terms of its potential non-inhalation risk to human health and the enviroment. Chemical rankings in the WMPT are identified by assigning scores (low (1), medium (2), and high (3) with highest aggregate score possible using this process being a 9) to each chemical considered to be of PBT concern. Although persistence, bioaccumulation, and toxicity are predictors of potential chronic risk, these chemical properties and their scores do not indicate absolute risk, but are a starting point in assessing their risk. To screen coke oven constituents for their PBT concern, we selected a cut-off score of 7. This approach ensured that HAPs of interest represented at least a moderately high concern for PBT. Table 3-4 presents the list of coke oven HAPs resulting when the coke oven constituent HAP list (Table A-1) was compared with the PBT list. Metals were not included in the initial HAP selection screen due to limitations of the Tool. Therefore, the metal constituents listed in Table A-1 were added. These are cobalt, mercury, lead, nickel, beryllium, antimony, cadmium, zinc, selenium, chromium, arsenic, and manganese.

To further refine the HAP selection process, we used criteria from the National Waste Minimization Partnership Program. The focus of this program is the reduction or elimination of the generation of hazardous waste containing a subset of 30 Waste Minimization Priority Chemicals[7]. These chemicals have been identified as the highest priorities for waste minimization based on PBT consideration. These 30 chemicals include twenty-seven organic chemicals and three metals. When the HAPs listed in Table 3-4 were compared with chemicals on the Waste Minimization Priority Chemicals list, all HAPs in that table with the exception of 2-Methylnaphthalene, were identified as potential PBT candidates. Similarly, when the metals from both lists were compared, only cadmium, mercury, and lead were selected.

EPA used information from a variety of data sources (see Appendix C: Documentation of the Emission Estimates) to estimate emissions for those coke oven constituents that were included in the multipathway screen. Information was available for most of the constituents identified with the exception of mercury. The emission test results done at ABC Coke which has coke batteries similar to the ones

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[7] This document may be found at: http://www.epa.gov/epaoswer/hazwaste/minimize/chemlist.htm

analyzed in this assessment, was not able to detect mercury in the emission streams above the non-detect level (0.2µg). While mercury is known to be present in coal, the starting material for making coke, it's fate during the combustion of coal in power plants is different than its fate during the coking process. Studies performed in Europe (Fisher, 1992) to track the fate of metals during cokemaking, lead to the conclusion that volatile metals like mercury, were distilled from the coal in the first few hours of the coking process and captured (along with volatiles such as benzene) in the coal tar which is sent to the By-product recovery process. While it is possible there may be some mercury emissions from battery emission points at these coke facilities, the data we have were not sufficient to develop quantitative estimates of those emissions for this risk assessment. Further, based on the European study, it is likely that the levels of these emissions would be low from those emission sources associated with the batteries.

Table 3-4. Constituent HAPs Selected Using the Draft Prioritization Chemical List[1]

CAS	Coke Oven Emissions Constituent HAPs
207089	Benzo(k)fluoranthene
205992	Benzo(b)fluoranthene
50328	Benzo(a)pyrene
193395	Indeno(1,2,3-cd) pyrene
56553	Benz(a)anthracene
206440	Fluoranthene
218019	Chrysene
129000	Pyrene
86737	Fluorene
83329	Acenaphthene
91576	2-Methylnaphthalene
120127	Anthracene

[1] Metals are not included in this tool. Those listed as being part of the universe of coke oven constituents were further screened against the Waste Minimization Priority Chemicals List described above.

3.2.1 Multipathway Exposure Assessment

The multipathway exposure screening assessment for coke oven batteries included exposures due to ingestion only. The sources of ingestion risk include contaminated food, soil, and drinking water. Air concentration and deposition rate estimates derived from the ISCST3 model outputs from the inhalation screening-level assessment, were used as inputs to the Indirect Exposure Model Version 2M (IEM-2M) (see Tables A-10 to A-31 for the concentrations, estimates, an model inputs used in this assessment). IEM-2M is a spreadsheet model developed for the *Mercury Study Report to Congress* (US EPA, 1997c), which uses a calculation approach similar to the *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (US EPA, 1998). This model was used by EPA to address multiple pollutants in a residual risk case study assessment on secondary lead smelters and was reviewed by EPA's science advisory board (US EPA, 2000). In addition to air pollutant concentrations and deposition rates, the IEM-2M model requires inputs on human exposure factors, and transfer and accumulation factors for pollutants in various environmental media and animal groups.

This screening assessment considered the "subsistence farmer" scenario as described in the secondary lead case study (U.S. EPA 2000b). This scenario reflects an adult living on a farm and consuming meat, dairy products, and vegetables that the farm produces. The animals raised on the farm subsist primarily on forage that is grown on the farm. We also assumed that the farm family fishes in nearby waters at a recreational level, and that they eat the fish they catch. We obtained ingestion rates and other exposure factors for this scenario from the EPA's *Exposure Factors Handbook* (US EPA, 1997b). The overall approach is summarized in the text box.

Steps in Assessment Included:

- Run the IEM-2M model using maximum concentration and deposition values
- Identify which chemicals and routes of exposure contribute the largest portion of overall cancer and noncancer risks
- Identify default input values and assumptions which have a large influence on results, and determine whether these default values are appropriate
- Replace default inputs which have a large influence on results with site-specific values for the modeled plant if possible
- Determine blood lead levels in children

The IEM-2M model was run using the highest concentrations and deposition rates estimated by the ISCST3 model. To compute water body impacts, we used a default value for water body size, flow rate, watershed size, and other parameters, based on a health protective scenario analyzed in the *Mercury Study Report to Congress* (US EPA, 1997c). For this current analysis, we applied the maximum pollutant deposition rates to the entire watershed. Risk estimates were dominated by the beef consumption, fish consumption, and produce consumption pathways.

In a refinement of the analysis, State and local air pollution control agencies were contacted to obtain estimates for the locations of the nearest agricultural lands to each of the four facilities. Predicted concentrations and depositions for these agricultural areas were used as inputs to IEM-2M. Also, the maximum deposition rates values used were replaced with average values for a watershed of the size analyzed in the mercury study. The watershed was assumed to be centered at the center of the facility with a radius of 3.5 km. The other default watershed inputs, such as flow rate, were retained.

As noted earlier, meat and vegetable ingestion rates were based on average values from the EPA *Exposure Factors Handbook*. However, the estimated concentrations of PAH in meat (including fish) and dairy products should be viewed as overly health protective, since they may not adequately account for metabolic processes that consume PAH compounds in animal tissues. In addition, the estimated concentrations of PAH in home-grown produce do not take into account the possibility that some of the PAH deposited to plants could be washed off by precipitation events, or by hand washing prior to human consumption. Estimated concentrations of PAH in cattle forage also do not take into account the possibility of wash-off during precipitation events. The IEM-2M model predicts that about half of the PAH deposited to plants is in the form of particulate matter, which could be washed off prior to ingestion by the cattle. For this analysis, no adjustments were made to account for possible wash off of deposited HAPS.

The bioaccumulation factors (BAF's) used to estimate PAH concentrations in beef and dairy products were reviewed for their appropriateness. The initial factors used were based on a correlation developed by Travis and Arms (Travis and Arms, 1988) that relates BAF's octanol-water partition coefficients to measured BAF's for other organic chemicals[8]. Hofelt et al. (2001) have contended that the Travis and Arms correlation does not adequately account for metabolism of PAH compounds in animal tissues, which would reduce the concentrations of the compounds in meat and dairy products. To partially account for this, the BAFs for PAH compounds for the IEM-2M model were updated using data from a study by Birak *et al* (Birak et al, 2001). No adjustment to consider PAH metabolism in beef, as suggested by Hofelt et al. (2001), was included in this analysis. That factor could have reduced PAH risk form beef consumption by an addiational factor of 100.

A further refinement replaced the default water body parameters in IEM with parameters for the nearest major water bodies to the facilities. Three of the facilities are located on the banks of rivers, and the forth is on the shore of Lake Erie. The following water bodies were modeled: the Ohio River for the Ashland, Kentucky facility; the Miami River for the Middletown, Ohio facility, the Niagara River for the Tonawanda, New York facility; and Lake Erie for the Erie, Pennsylvania facility. We modeled effective watersheds with a 3.5 kilometer radius for the three riverside facilities, and a 50 kilometer radius for the Lake Erie facility. Actual flow velocities were obtained for the rivers. The flowrate in Lake Erie was assumed to be 0.

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[8] The octanol-water partition coefficient (K_{ow}) is defined as the ratio of the concentration of a chemical in octanol to its concentration in water which is at equilibrium with the water. This constant is used in IEM-2M as an indicator of the chemical's partitioning between a lipid phase and a water phase in animal tissues (and also between a soil phase and a water phase).

Two estimates of risk were developed for the subsistence farmer scenario: a central tendency estimate, and a high-end exposure estimate. For the central tendency estimate, all transport and exposure variables were set to central tendency values (near the 50th percentile or the mean). For the high-end exposure case, we used 90th percentile levels for the farmer's consumption of contaminated foods and exposure duration, in accordance with EPA guidance (US EPA, 1989). All exposure factors were obtained from the EPA's *Exposure Factors Handbook* (US EPA, 1997b). These factors generally reflect average values based on surveys for farms operating on a subsistence basis. Emissions estimates and fate and transport assumptions remained the same for both scenarios. A more detailed list of input values is given in Appendix A, Tables A-10 to A-18.

Screening for the effects of lead exposure and estimating the potential blood lead levels in children was done separately. For this purpose, previous outputs from the ISC and IEM-2M modeling were used as inputs into the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) (US.EPA, 1994a,b). These were primarily the lead air concentrations estimated by ISCST3 and the media concentrations estimated from the IEM-2M. We focused this assessment on the AK-Steel, Ashland facility because among the 4 coke facilities, it had the highest screening level inhalation risk, hazards, and estimated air concentrations. The major outputs are the blood lead levels for children ages 6 months to 7 years based on central tendency and the 90th percentile exposure values. These are presented in Appendix A along with a more detailed discussion of this part of the multipathway screening assessment.

3.2.2 Results of Multipathway Exposure Assessment

Table 3-5 shows the estimated location of the nearest farms to each of the facilities. In the case of the AK-Steel Ashland facility, local air pollution agency personnel confirmed that the nearest agricultural land to the facility is actually being used for grazing cattle and growing vegetables. Table 3-6 summarizes the estimated ingestion cancer risks and chronic hazard indices for the ingestion route of exposure based on the final multipathway analysis.

For the central tendency exposure case under the subsistence farmer scenario, estimated ingestion cancer risks range from 3×10^{-7} to 7×10^{-6} across the four facilities. When high-end exposure variables are used, estimated cancer risks range from 1×10^{-6} to 3×10^{-5}. The predicted cancer risks result mainly from PAH emissions. The highest estimated cancer risks are for the AK Steel-Ashland facility which has the highest PAH emissions. In general, the predicted ingestion cancer risk is dominated by ingestion of PAH contaminants in meat, dairy products, and home-grown produce for the Ashland facility and the two other riverside facilities.

The central tendency estimates of ingestion HI's range from 0.00002 to 0.0004 for the four facilities. When high-end exposure parameters are used, estimated ingestion HI's range from 0.00004 to 0.001 for the four facilities. Like the cancer risks, the predicted ingestion HIs result primarily from PAH emissions. The predicted ingestion cancer risk is dominated by ingestion of home-grown produce for the AK-Steel Ashland facility and the two other riverside facilities.

A comparison of the inhalation cancer risk data in Table 3-3 with the results presented in Table 3-6 shows that predicted ingestion risk is less than the predicted inhalation risk (the predictions range from 23x to 285x less when the central tendency data are considered and from 7x to 100x less when using the higher end parameters data. Although the HAPs tested in the inhalation and ingestion screens do not overlap completely, (i.e., each set of HAPs were selected for different reasons), there is sufficient overlap to say that predicted risks to the exposed population are driven by the inhalation pathway.

Table 3-5 Locations of Agricultural and Water Body Receptors Analyzed in the Multipathway Analysis

	Location of Agricultural Land Receptors and Water Bodies			
Facility Name	**Distance from Facility (km)**	**Compass Direction**	**Name of Water Body**	**Radius of Analyzed Effective Watershed (km)***
AK Steel-Ashland	2.6	WSW	Ohio River	3.5
AK Steel-Middletown	3.0	WNW	Miami River	3.5
Erie Coke	11.0	SSE	Lake Erie	50.0
Tonawanda	1.7	W	Niagara River	3.5

*Centered on the facility

Table 3-6 Summary of Risk Estimates for Subsistence Farmer Exposure Scenario[1]

Exposure Route	AK Steel Ashland	AK Steel Middletown	Erie Coke	Tonawanda
Ingestion Cancer Risk - Central Tendency				
Soil ingestion	9×10^{-9}	4×10^{-9}	3×10^{-10}	2×10^{-9}
Produce	4×10^{-6}	1×10^{-6}	1×10^{-7}	6×10^{-7}
Meat and dairy products	3×10^{-6}	1×10^{-6}	1×10^{-7}	7×10^{-7}
Water	2×10^{-10}	2×10^{-9}	9×10^{-10}	4×10^{-11}
Fish	6×10^{-9}	5×10^{-8}	6×10^{-8}	2×10^{-9}
Total Ingestion	**7×10^{-6}**	**2×10^{-6}**	**3×10^{-7}**	**1×10^{-6}**
Ingestion Cancer Risk - High End				
Soil ingestion	3x10^{-8}	1x10^{-8}	1x10^{-9}	9x10^{-9}
Produce	2x10^{-5}	7x10^{-6}	5x10^{-7}	3x10^{-6}
Meat and dairy products	1x10^{-5}	5x10^{-6}	5x10^{-7}	3x10^{-6}
Water	5x10^{-10}	6x10^{-9}	3x10^{-9}	1x10^{-10}
Fish	3x10^{-8}	2x10^{-7}	3x10^{-9}	9x10^{-9}
Total Ingestion	**3x10^{-5}**	**1x10^{-5}**	**1x10^{-6}**	**6x10^{-6}**
Ingestion Non Cancer Hazard Indices - Central Tendency				
Soil ingestion	2×10^{-6}	6×10^{-7}	6×10^{-8}	4×10^{-7}
Produce	4×10^{-4}	1×10^{-4}	9×10^{-6}	5×10^{-5}
Meat and dairy products	4×10^{-5}	1×10^{-5}	1×10^{-6}	5×10^{-6}
Water	7×10^{-8}	9×10^{-7}	1×10^{-7}	1×10^{-8}
Fish	3×10^{-6}	2×10^{-5}	7×10^{-6}	5×10^{-7}
Total Ingestion	**4×10^{-4}**	**1×10^{-4}**	**2×10^{-5}**	**6×10^{-5}**
Ingestion Non Cancer Hazard Indices - High End				
Soil ingestion	4x10^{-6}	1x10^{-6}	1x10^{-7}	8x10^{-7}
Produce	1x10^{-3}	3x10^{-4}	2x10^{-5}	1x10^{-4}
Meat and dairy products	8x10^{-5}	3x10^{-5}	2x10^{-6}	1x10^{-5}
Water	1x10^{-7}	1x10^{-6}	2x10^{-7}	2x10^{-8}
Fish	5x10^{-6}	6x10^{-5}	2x10^{-5}	1x10^{-6}
Total Ingestion	**1x10^{-3}**	**4x10^{-4}**	**4x10^{-5}**	**1x10^{-4}**

[1] Results from which these summary data were derived may be found in Appendix A, Tables A-31 to A-34

The results for the blood lead level determination is presented in Table 3-7. These results show that the estimated blood lead levels for potentially exposed children living near the AK-Ashland facility never exceeded a level of 0.1 µg/dL (microgram per deciliter). It is not likely that children living around the other coke facilities would experience a lead exposure greater than this. A more complete presentation of inputs may be found in Appendix A, Tables A-19 to A-30.

Table 3-7. Results of IEUBK Modeling for AK Steel - Ashland, KY

Age	Blood Lead Level (µg/dL)*	
	Central Tendency Exposure Scenario	High-End Exposure Scenario
<1	< 0.1	**0.1**
1-2	< 0.1	< 0.1
2-3	< 0.1	< 0.1
3-4	< 0.1	< 0.1
4-5	< 0.1	< 0.1
5-6	< 0.1	< 0.1
6-7	< 0.1	< 0.1

* The blood lead level that is currently used to determine if a hazard exists is 10 µg/dL (see discussion of lead in Appendix B).

3.3 Screening Ecological Assessment

The screening-level risk assessment was done using the same methods as in the secondary lead smelters case study (US EPA, 2000) and was intended to identify HAPs which may pose a potential risks to ecological receptors. It used chronic toxicity screening values which are estimates of the maximum concentration that should not affect survival, growth, or reproduction of sensitive species after long-term (>30 days) exposure to HAPs. The results are not intended for use in predicting specific types of effects to individuals, species, populations, or communities or to the structure and function of the ecosystem, but as an indicator of where more analysis may be needed if screening -level health values are exceeded. In general, for all media and HAPs, we selected conservative screening values available for use in this analysis. Also, we assumed 100% of each HAP to be bioavailable. Table 3-9 lists the endpoint used in the derivation of each screening value.

The assessment endpoints for this screening-level ecological risk analyses were the structure and function of generic aquatic and terrestrial populations and communities, including threatened and endangered species, that might be exposed to HAP emissions from the four coke oven facilities. The assessment endpoints were relatively generic with respect to descriptions of the environmental values that are to be protected and the characteristics of the ecological entities and their attributes. It was assumed that these ecological receptors were representative of sensitive individuals, populations and communities present near the four coke oven facilities. The principal potential exposure pathways to HAPs for these ecological receptors in the screening-level ecological risk analyses included the following:

- Aquatic organisms (e.g., fish, invertebrates, algae): direct contact with surface water
- Aquatic organisms: ingestion of HAP-contaminated food
- Benthic organisms: direct contact with sediment and surface water
- Soil organisms, including earthworms and microbes: direct contact with soil
- Terrestrial plants: direct contact with HAPs in the soil
- Terrestrial plants: direct contact with HAPs in the ambient air
- Terrestrial wildlife: ingestion of HAP-contaminated water
- Terrestrial wildlife: ingestion of HAP-contaminated soil
- Terrestrial wildlife: inhalation of HAPs in the ambient air
- Herbivorous wildlife: ingestion of HAP-contaminated vegetation
- Piscivorous wildlife: ingestion of HAP-contaminated fish
- Carnivorous wildlife: ingestion of HAP-contaminated, herbivorous wildlife

The HAPs included in the assessment were the metals, cadmium and lead, and 11 polycyclic aromatic hydrocarbons (PAHs), including anthracene, benzo(a)pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno-123(cd)pyrene, acenaphthene, fluoranthene, fluorene, and pyrene. The exposure assessment estimated concentrations of contaminants to which aquatic and terrestrial biota are potentially exposed. These estimated concentrations were based on media concentrations calculated for each facility for the human health assessment using the models, ISCST3 and IEM-2M discussed previously (see Section 3). The media concentration data used in the ecological exposure assessment included concentrations in air; plants consumed by humans (i.e., grains, legumes, root vegetables, fruits, and leafy vegetables); animal products consumed by humans (i.e., beef and pork); tilled and non-tilled agricultural soils; fish; total and dissolved surface water concentrations; total sediment concentrations; dissolved sediment concentrations; and total watershed soil concentrations. We selected these receptors because they are considered representative of generic populations and communities most likely to be exposed to the HAPs near the four coke oven facilities. Table 3-8 lists the HAPs, ecological receptors, and exposure media and pathways evaluated for each ecological receptor.

Table 3-8. Chronic Ecological Screening Values, Receptors, and Media Evaluated

HAP	Benthic Life/ Sediment (μg/g)	Earthworms and Microbial Processes/ Soil (mg/Kg)	Aquatic Life/ Water (μg/L)	Plants		Terrestrial Wildlife Receptor/Exposure Pathway						
				Air (μg/m^3)	Soil (mg/kg)	NOAEL mg/kg /day	Herbivore/ Forage (mg/Kg)	Piscivore/ Fish (mg/Kg)	Vertebrates /Water (mg/L)	Vertebrates /Air (μg/m^3)	Carnivores/ Herbivores (mg/Kg)	Vertebrates/ Soil (mg/Kg)
Acenaphthene	0.01[16]		23[5]		20[8]	175[18] Mouse	350[4] Cottontail Rabbit	385[4] River Otter	403[4] Whitetail Deer	133,350[4] Cottontail Rabbit	508[4] Red Fox	2678[4] Short-tail Shrew
Anthracene	0.02[16]		0.73[5]			100[4] Mouse	200[4] Cottontail Rabbit	220[4] River Otter	230[4] Whitetail Deer	76,200[4] Cottontail Rabbit	290[4] Red Fox	1530[4] Short-tail Shrew
Benzo(a) anthracene	0.004[16]		0.03[5]									
Benzo(a)pyrene	0.0096[16]	0.7[1]	0.014[5]			1.0[4] Mouse	2.0[4] Cottontail Rabbit	2.2[4] River Otter	2.3[4] Whitetail Deer	762[4] Cottontail Rabbit	2.9[4] Red Fox	15.3[4] Short-tail Shrew
Benzo(b) fluoranthene	0.3[16]											
Benzo(k) fluoranthene	0.0026[16]		0.14[7]									
Chrysene	0.009[16]		0.006[16]									
Fluoranthene	0.02[16]	100[17]	6.16[5]			13.2[4] Mouse	26.4[4] Cottontail Rabbit	29.0[4] River Otter	30.4[4] Whitetail Deer	10,058[4] Cottontail Rabbit	38.3[4] Red Fox	202[4] Short-tail Shrew
Fluorene	0.01[16]	30[9]	3.9[5]			12.5[4] Mouse	25[4] Cottontail Rabbit	27.5[4] River Otter	28.8[4] Whitetail Deer	9525[4] Cottontail Rabbit	36.3[4] Red Fox	191[4] Short-tail Shrew
Ideno-123(cd)pyrene	0.0104[16]											

Table 3-8. Chronic Ecological Screening Values, Receptors, and Media Evaluated

HAP	Benthic Life/ Sediment (µg/g)	Earthworms and Microbial Processes/ Soil (mg/Kg)	Aquatic Life/ Water (µg/L)	Plants		Terrestrial Wildlife Receptor/Exposure Pathway						
				Air ($\mu g/m^3$)	Soil (mg/kg)	NOAEL mg/kg /day	Herbivore/ Forage (mg/Kg)	Piscivore/ Fish (mg/Kg)	Vertebrates /Water (mg/L)	Vertebrates /Air ($\mu g/m^3$)	Carnivores/ Herbivores (mg/Kg)	Vertebrates/ Soil (mg/Kg)
Pyrene	0.02[16]		0.025[16]			75[4] Mouse	150[4] Cottontail Rabbit	165[4] River Otter	173[4] Whitetail Deer	57,150[4] Cottontail Rabbit	218[4] Red Fox	1148[4] Short-tail Shrew
Cadmium	0.2[16]	20[9]	1.1[5]		3[8]	1 Rat[4] 1.45 Mallard Duck[4]	3.6[4] Cottontail Rabbit	2.9[4] Belted Kingfisher	4.1[4] Whitetail Deer	1350[4] Cottontail Rabbit	5.1[4] Red Fox	28.2[4] Short-tail Shrew
Lead	23[16]	500[9]	3.2[5]		50[8]	8 Rat[4] 1.13 Jap. Quail[4]	30[4] Cottontail Rabbit	2.2[4] Belted Kingfisher	4.9[4] Rough-Winged Swallow	1855[4] American Woodcock	4.2[4] Barn Owl	225[4] Short-tail Shrew

Screening value is for the toxicity of benzo(a)pyrene to soil microorganisms and microbial processes, not toxicity to earthworms.

References: 1. CCME (1997);2. Haines et al. (2000); 3. Jones et al. (1997); 4. Sample et al. (1996); 5. Suter and Tsao (1996); 6. U.S. EPA (1993a); 7. U.S. EPA (1998); 8. Will et al. (1995a); 9. Will et al. (1995b); 10. EPT (1999); 11. US EPA (1985); 12. US EPA (1994); 13. US EPA (2000); 14. USDA (2001); 15. US EPA (1991); 16. MacDonald et al. (2000); 17. US EPA (2003)

3.3.1 Results of Ecological Screening Assessment

We screened HAPs, pathways and receptors using the hazard quotient (HQ) method, which is the ratio of the expected environmental concentration to the selected chronic screening value. HAPs with an HQ greater than one (HQ>1) are considered to indicate that potential ecological concern may exist. Appendix A (Tables A-35 to A-38) contain spreadsheets for each coke oven facility, showing all of the estimated exposure concentrations of the HAPs in each medium, the screening-level benchmarks, and the estimated HQs. These results show that for all HAPs, media, ecological receptors and exposure pathways analyzed, none of the 4 coke oven facilities had HQs >0.4.

Table 3-9. Endpoints used to Derive the Chronic Ecological Screening Values Listed in Table 3-8

HAP	Benthic/ Life Sediment	Earthworms and Microbial Processes/soil	Aquatic Life/ Water	Plants/ Soils	Terrestrial Wildlife Receptor/Exposure Pathway					
					Herbivore/ Forage	Piscivore/ Fish	Vertebrates/ Water	Vertebrates/ Air	Carnivores/ Herbivores	Vertebrates/ Soil
Acenaphthene	Lowest eco-tox. value		EPA water quality criteria	10th percentile, LOEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL
Anthracene	No effects threshold		EPA Tier II value		NOAEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL
Benzo(a) anthracene	Lowest eco-tox. value		EPA Tier II value							
Benzo(a) pyrene	Lowest eco-tox. value	10th percentile, LOEL	EPA Tier II value		NOAEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL
Benzo(b) fluroanthene	No effects threshold									
Benzo(k) fluroanthene	Lowest eco-tox. value		0.1 x lowest acute LC_{50}							
Chrysene	Lowest eco-tox. value		Eco-tox value; Netherlands							
Fluroanthene	No effects threshold	Lowest eco-tox. value	EPA water quality criteria		NOAEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL
Fluorene	No effects threshold	10th percentile, LOEL	EPA Tier II value		NOAEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL
Indeno-123 (cd)pyrene	Lowest eco-tox. value									
Pyrene	No effects threshold		Interim guideline		NOAEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL
Cadmium	No effects threshold	10th percentile, LOEL	EPA water quality criteria	10th percentile, LOEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL
Lead	No effects threshold	10th percentile, LOEL	EPA water quality criteria	10th percentile, LOEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL	NOAEL

3.4 Refined Inhalation Assessment

As the approach diagram (Figure 2-1) shows, step 2 in this process was to conduct screening-level assessments in order to narrow the scope of a more refined assessments. The results from the multipathway and ecological assessments show that the 2 metals and the 11 PAHs would not be carried forward into the refined assessment. The results of the inhalation screen allowed some HAPs, to be eliminated from further evaluation. Therefore for the more refined risk assessment, all 4 of the coke facilities were assessed for cancer, inhalation risk and only for the HAPs, coke oven emissions (as BSO), benzene, and arsenic while emissions from AK Steel–Ashland were assessed for the potential noncancer effects due to arsenic and benzene exposures.

Appendix D provides a description of the dispersion modeling for the coke ovens assessment; Appendix E provides plume rise calculations; and Appendix F presents the source parameters (e.g., stack heights, exit velocities, source configurations) used in the dispersion modeling. Source parameters describe the physical characteristics of the various emission points, which affect the dispersion of emissions.

3.4.1 Maximum Risks

The results of the refined risk assessment (presented in Table 3-10) show that the estimated lifetime, facility-level, cancer risks, (i.e., based on a 70 year exposure duration) exceed 1 in a million ($1x10^{-6}$) for all 4 facilites with a maximum risk ranging from 50 in a million ($5x10^{-5}$) to 500 in a million ($5x10^{-4}$). The AK Steel - Ashland receptor which shows the highest estimated maximum risk of 500 in a million ($5x10^{-4}$), is in an area that is currently inhabited.

Table 3-10. Inhalation Cancer Risk and Hazard Quotient for Exposed Population

Site	Facility-Level Maximum Risk [a]	Hazard Quotient
AK Steel–Middletown	$5x10^{-5}$	NI[b]
AK Steel–Ashland	$5x10^{-4}$	Benzene → 0.4 Arsenic →0.07
Erie Coke	$1x10^{-4}$	NI
Tonawanda	$1x10^{-4}$	NI

[a] Maximum risk at 70 year exposure duration

[b] NI = not included in analysis

Results reflect exposure from all emission sources, (i.e., MACT I, MACTII, and the By-Product Recovery Plant)

This assessment also shows that for the one facility (AK Steel - Ashland) for which non-cancer hazards were assessed, the facility-level HQs within the 50 km site, were 0.07 for arsenic and 0.4 for benzene. Tables I-1 to I-4 in Appendix I present a cumulative risk probability distribution based on a 70 year exposure duration. In these tables, the facility-level, (i.e., emissions from MACT I, MACT II, and the By-Product emission sources) cumulative risk data is calculated using the "All Source" population counts in each risk bin. The population counts at each risk level are summarized in Table 3-11. As suggested by the percent contribution to coke oven emissions (Tables 2-3 and 3-14), the data in the tables in Appendix I show that the primary contributors to risks above 1 in a million ($1x10^{-6}$) are generally the MACT I and MACT II emission sources. The 70 year exposure duration risk ranges are graphically presented in Figures 3-1 to 3-4.

To provide a sense of how variations in residency times may affect risk levels, we conducted a simple analysis (see Table 3-12) of the maximum risk level at each coke facility. The national residency data was derived from EPA's Exposure Factors Handbook (US EPA, 1997b). We did not consider any variations in exposure due to daily activity patterns in this analysis. Results indicate that maximum individual risks would be expected to be within a factor of 10 lower, , (i.e., the 50th percentile of residency data is 9 years).

Table 3-11 Population Counts by Risk Range

Risk Bin	Exposure Duration	AK Steel Middletown	AK Steel Ashland	Erie Coke	Tonawanda
> $1x10^{-4}$	70 years	0	279	0	0
> $1x10^{-5}$	70 years	13,964	31,836	6,996	1,629
> $1x10^{-6}$	70years	244,379	226,830	120,936	314,097
$\leq 1x10^{-6}$	70 years	2,069,077	121,003	205,227	847,596
Total Population[1]		2,327,420	397,948	333,159	1,163,322

[1] US Census for 2000 is source of population data.. Total population around all facilities = approx. 4.2 million. We did not include populations across international borders in our risk assessments. Emissions from the 2 facilities (Erie and Tonawanda) which are closest to Canada, are not likely to impact the Canadian population greatly. Erie Coke is more than 50 miles across Lake Erie from the Canadian population. This is beyond the modeling range we did. Additionally, the prevailing winds around these lakes are predominately southwest to northeast. For both Erie Coke and Tonawanda (which is closer to the Canadian population), their emissions are more likely to disperse away from the Canadian populations.

Table 3-12. Effect of Exposure Duration on Maximum Individual Risk

Percentile	AK Steel–Middletown	AK Steel–Ashland	Erie Coke	Tonawanda
Facility				
50	$6x10^{-6}$	$6x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$
75	$1x10^{-5}$	$1x10^{-4}$	$3x10^{-5}$	$3x10^{-5}$
90	$2x10^{-5}$	$2x10^{-4}$	$5x10^{-5}$	$5x10^{-5}$
95	$3x10^{-5}$	$3x10^{-4}$	$6x10^{-5}$	$6x10^{-5}$
100 *	$5x10^{-5}$	$5x10^{-4}$	$1x10^{-4}$	$1x10^{-4}$
MACT I				
50	$3x10^{-6}$	$3x10^{-5}$	$9x10^{-6}$	$6x10^{-6}$
75	$5x10^{-6}$	$5x10^{-5}$	$2x10^{-5}$	$1x10^{-5}$
90	$9x10^{-6}$	$9x10^{-5}$	$3x10^{-5}$	$2x10^{-5}$
95	$1x10^{-5}$	$1x10^{-4}$	$4x10^{-5}$	$3x10^{-5}$
100 *	$2x10^{-5}$	$2x10^{-4}$	$7x10^{-5}$	$5x10^{-5}$

* The 100 percentile values for each coke facility are taken from Table 3-10. The 100 percentile values for MACT I sources are taken from Table 3-14 and Tables I-1 to I-4. Residency duration data taken from Table H-1. In this table the 50th percentile of residency is 9 years, the 100 percentile is 70 year exposure.

3.4.2 Annual Cancer Incidence

Table 3-13 presents the estimated annual number of cancer cases associated with 70 years of exposure to the estimated concentrations of HAPs emitted from coke oven facilities, and Table 3-14 shows the different emission points' percent contribution to that annual cancer incidence. Of the emissions associated with coke batteries (i.e., charging, doors, lids, offtakes), door leaks are clearly the major contributor. This is to be expected since inhalation risk is linearly related to emissions, and door leaks are the primary source of battery emissions (see Table C-4). In addition, it can be seen that for the facility, door leaks and pushing fugitives account for similar proportions of risk (average of 34% and 37%, respectively) and have similar emission rates (see Tables C-5 and C-7 in Appendix C.)

Table 3-13. Annual Cancer Incidence by Emission Point [1]

Facility	MACT I		Byproduct plant	MACT II		Total Annual	Total Lifetime
	Door leaks	Charging, lid leaks, and offtake leaks		Pushing Fugitives	Quenching		
AK Steel - Middletown	$1.1x10^{-2}$	$1.9x10^{-3}$	$6.4x10^{-4}$	$1.3x10^{-2}$	$9.2x10^{-3}$	$3.6x10^{-2}$	2.5
AK Steel - Ashland	$8.4x10^{-3}$	$1.3x10^{-3}$	$2.3x10^{-3}$	$1.1x10^{-2}$	$9.5x10^{-3}$	$3.3x10^{-2}$	2.3
Erie Coke	$4.8x10^{-3}$	$5.6x10^{-4}$	$3.0x10^{-5}$	$4.2x10^{-3}$	$1.4x10^{-3}$	$1.1x10^{-2}$	.8
Tonawanda	$7.8x10^{-3}$	$8.8x10^{-4}$	$1.3x10^{-3}$	$8.8x10^{-3}$	$4.2x10^{-3}$	$2.3x10^{-2}$	1.6

[1] Sources of data for calculating the emission point specific incidence are:

Source-specific incidence data calculated from risk and population information in Table I-1

Emissions ratios for apportioning MACT I emissions between doors and other MACT I emissions, (i.e., charging, lid and offtake leaks) come from Table C-5.

These data are based on a 70 year exposure duration, (i.e., the data in Appendix I).

Table 3-14. Percent Contribution to Annual Cancer Incidence by Emission Point *

Facility	MACT I		Byproduct plant	MACT II		Total
	Door leaks	Charging, lid leaks, and offtake leaks		Pushing fugitives	Quenching	
AK Steel - Middletown	31	5.4	1.8	36	26	100
AK Steel - Ashland	26	4.1	7.1	34	29	100
Erie Coke	44	5.1	0.3	38	13	100
Tonawanda	34	3.8	5.7	38	18	100
Average	34	4.6	3.7	37	22	100

* Source of data: Tables 2-3 and C-5

3.4.3 Risks for MACT I Sources: Actual Emissions and 2010 LAER Limits

The risk results reported above are based on 1993 MACT I allowable emission limits for doors, lids, offtakes, and charging. In order to provide a broader picture of potential risks, risk estimates based on the 2010 LAER limits and actual emissions were calculated for comparison. Risks for these latter two cases were derived from the ratio of these emissions to the MACT I allowable emissions. Table 3-15 presents these estimated risk numbers.

Table 3-15. Maximum Risks for MACT I Sources

Site Id	Risk (Allowable)[1]	Emissions Ratio (Actual/Allowable)[2]	Risk (Actual)	Emissions Ratio (LAER/Allowable)[2]	Risk (LAER)
AK Steel Middletown	$2x10^{-5}$	0.59	$1.2x10^{-5}$	0.81	$1.6x10^{-5}$
AK Steel Ashland	$2x10^{-4}$	0.71	$1.4x10^{-4}$	0.90	$1.8x10^{-4}$
Erie Coke	$7x10^{-5}$	0.58	$4.1x10^{-5}$	0.88	$6.2x10^{-5}$
Tonawanda	$5x10^{-5}$	0.65	$3.3x10^{-5}$	0.88	$4.4x10^{-5}$

[1] Allowable risk data taken from Table I, Appendix I and are the first risk values where populations are noted for MACT I sources.

[2] Actual and LAER ratios derived from data in Tables C-3,C-4, and C-6 in Appendix C. When 2 batteries exist at one facility, the emission estimates were combined to calculate the ratios, e.g., Erie Coke allowables = .76 + 1.16 = 1.92 T/yr

As mentioned in Section 2, an analysis of more recent data on the cohort of coke oven workers used in deriving EPA's IRIS unit risk estimate and other data not available previously was performed by Moolgavkar and others (1998). The upper confidence level estimate from this analysis was $1.8x10^{-4}$, which is approximately 3.5 times lower than the current IRIS value. This analysis, however, did not comport with EPA methodology which, it is presumed, would have led to the derivation of a value closer to the current IRIS value (see Appendix B). Accordingly, use of the unadjusted Moolgavkar estimate would be expected to yield values for maximum individual cancer risk for the MACT I allowable emissions scenario no lower than the following: $6x10^{-6}$ for AK-Steel Middletown, $6x10^{-5}$ for AK-Steel Ashland, $2x10^{-5}$ for Erie Coke, and $1x10^{-5}$ for Tonawanda.[9] These values are contrasted with those derived from the IRIS URE (Table 3-15; 1st column): $2x10^{-5}$ for AK-Steel Middletown, $2x10^{-4}$ for AK-Steel Ashland, $7x10^{-5}$ for Erie Coke, and $5x10^{-5}$ for Tonawanda.

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[9] These values are calculated by multiplying the values in Table 3-15 by the Moolgavkar value divided by the EPA IRIS value. Although the original values in Table 3-15 are given the greater weight in decision making based on this assessment, these values are considered useful for their indication of the variation in coke oven emissions unit risk estimates derived via different methods and data.

Figure 3-1 Cancer Risk Isopleths Around AK-Steel Middletown

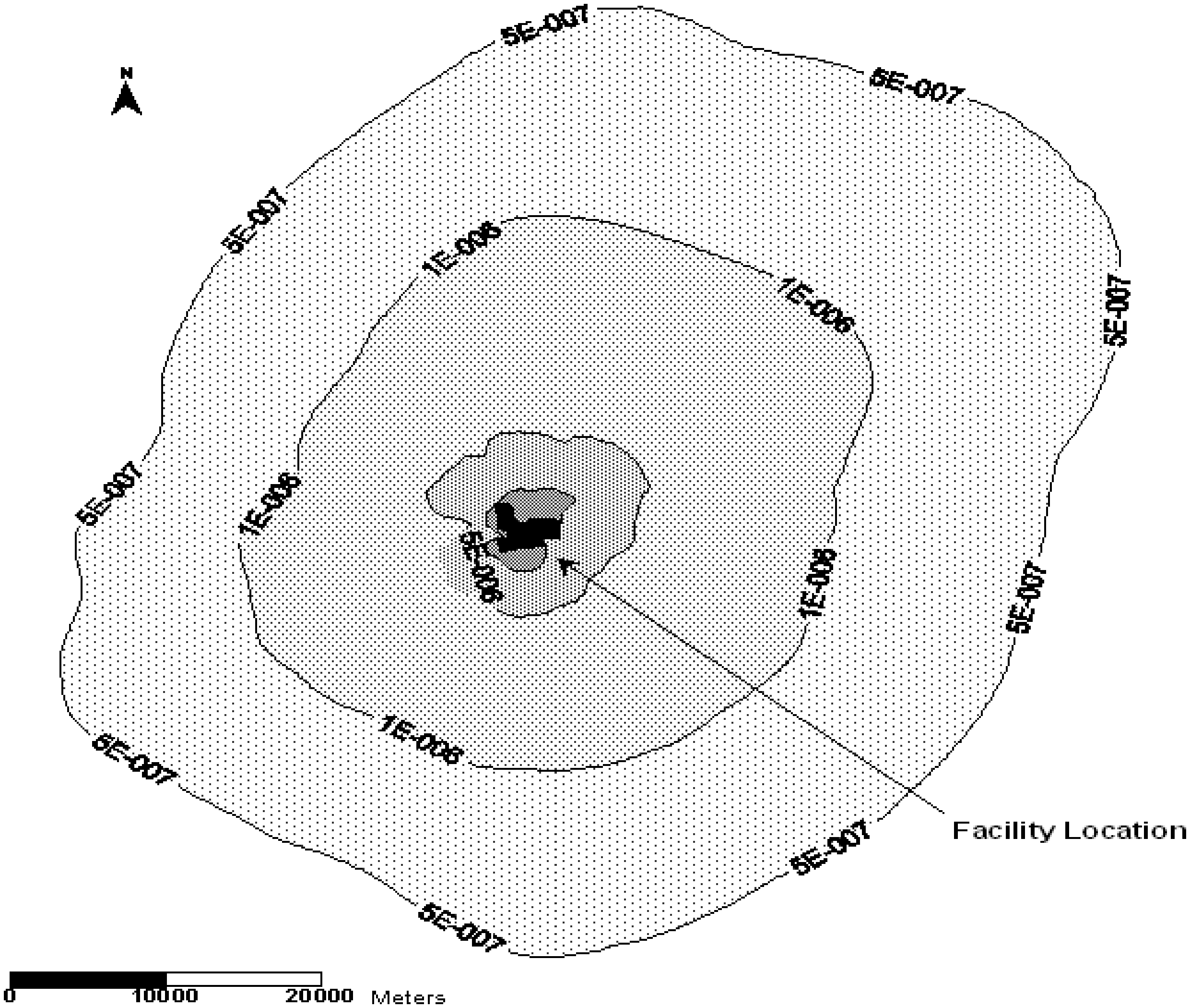


Figure 3-2 Cancer Risk Isopleths Around AK-Steel Ashland

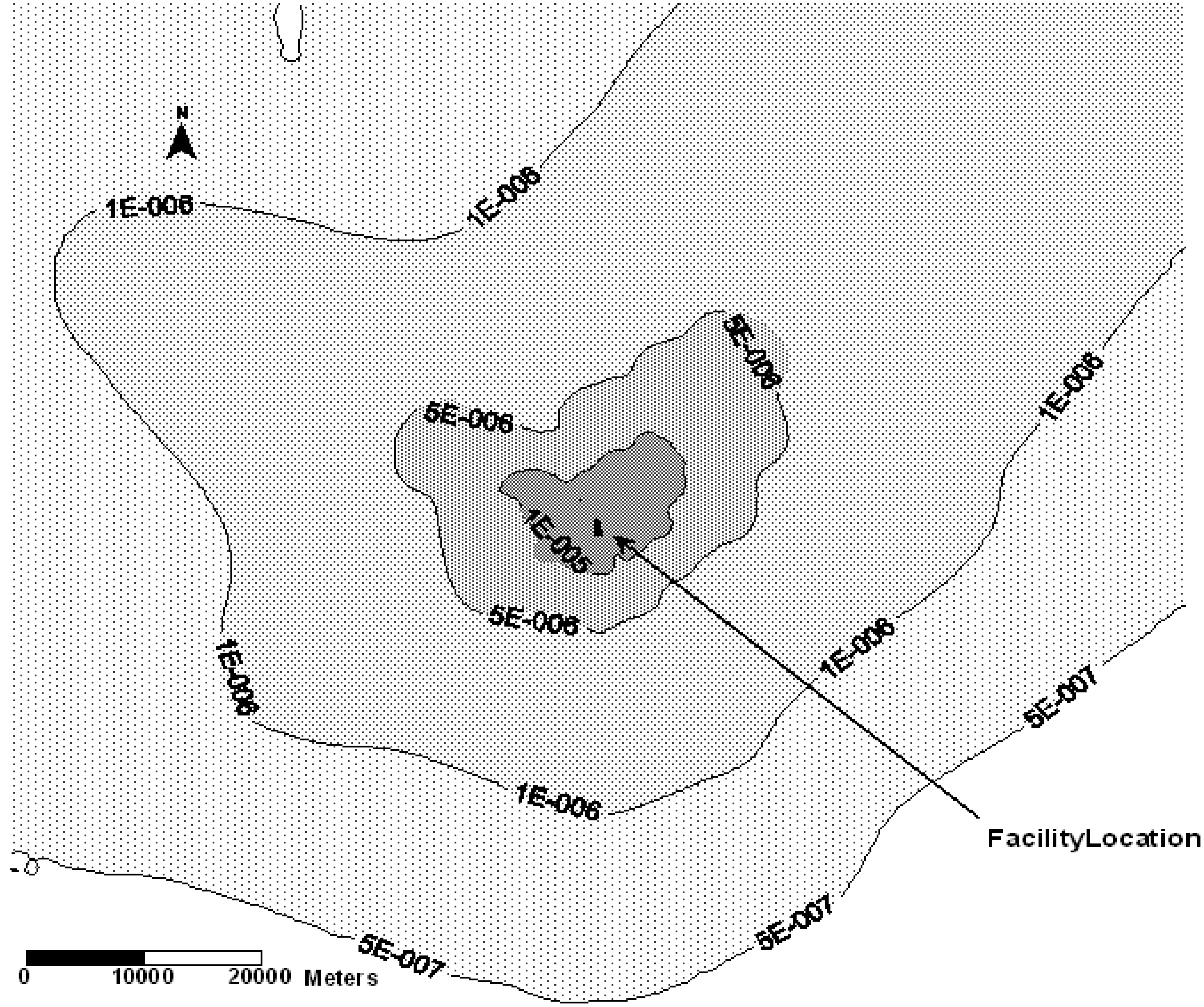


Figure 3-3 Cancer Risk Isopleths Around Erie Coke

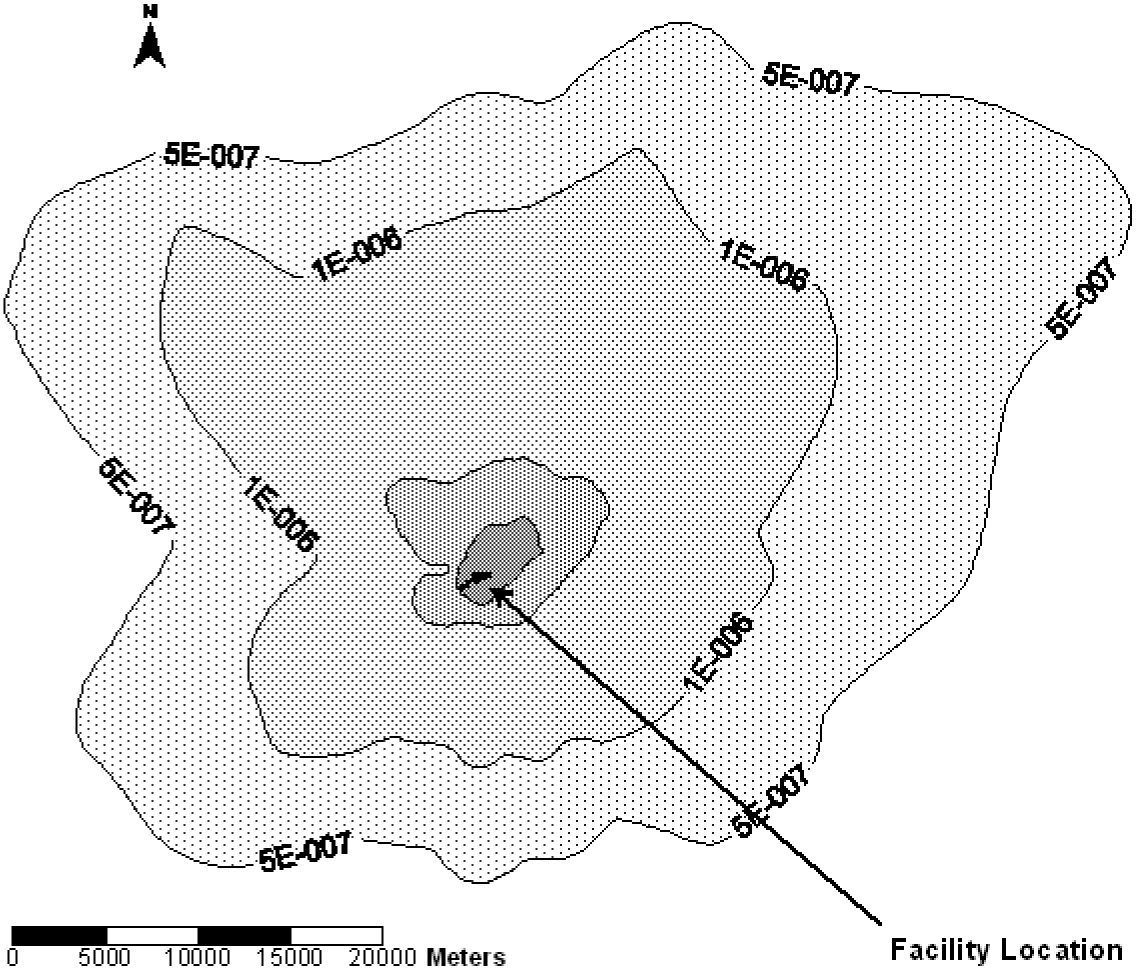
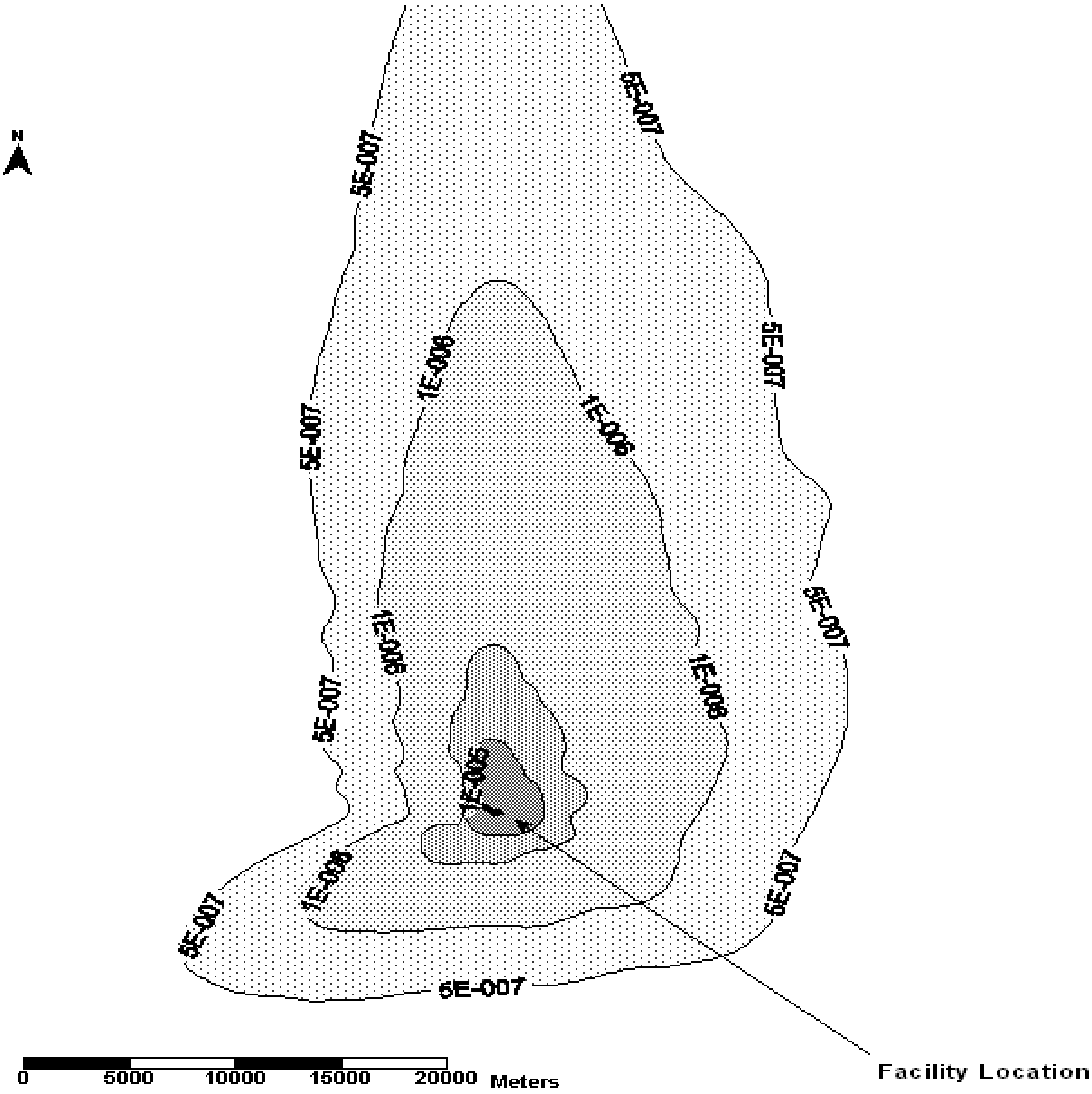


Figure 3-4 Cancer Risk Isopleths Around Tonawanda Coke



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Appendix A: Chemical Screening Analysis

The initial step in the screening was to establish the universe of constituents in coke plant emissions and to determine whether necessary emissions and toxicological data were available for each constituent. Appendix C characterizes the emissions from each coke plant source and presents the constituents known to be included in these emissions. The constituents were identified based on data in the literature and from EPA emission tests, as referenced in Appendix C. Table A-1 lists the 43 HAPs identified as being constituents of the HAP, coke oven emissions.

Table A-1. Universe of Constituents of Coke Oven Emissions

CAS	Constituent	CAS	Constituent
99992	Benzene soluble organics	98828	Cumene
71432	Benzene	106990	Butadiene
74908	Hydrocyanic acid	463581	Carbonyl sulfide
108883	Toluene	91576	2-Methylnaphthalene
91203	Naphthalene	192972	Benzo(e)pyrene
1330207	Xylene (mixed isomers)	205992	Benzo(b)fluoranthene
7439921	Lead	7723140	Phosphorus
85018	Phenanthrene	7647010	Hydrochloric acid (HCL)
50328	Benzo(a)pyrene	7664393	Hydrofluoric acid (HF)
208968	Acenaphthylene	75150	Carbon disulfide
7440382	Arsenic	7440473	Chromium
7440020	Nickel	7440439	Cadmium
206440	Fluoranthene	108952	Phenol
7439965	Manganese	7440484	Cobalt
129000	Pyrene	7440360	Antimony
218019	Chrysene	132649	Dibenzofuran
86737	Fluorene	106445	Cresol, p-
7782492	Selenium	7440417	Beryllium
120127	Anthracene	7439976	Mercury
56553	Benz(a)anthracene	95487	Cresol, o-
83329	Acenaphthene	207089	Benzo(k)fluoranthene
193395	Indeno(1,2,3-cd) pyrene		

Data to develop this list of coke oven emission constituents may be found in Appendix C: Documentation of emission estimates.

As described in Section 3, an inhalation screening level assessment was done in order to focus the scope of a refined assessment. The results for the HAP, coke oven emission, and its constituents include those for which cancer unit risk values exist and for those emission points where either 'coke oven emissions' are present (as BSO) or where the emission streams do not emit the HAP, coke oven emissions, but a portion of the mixture, (i.e., the constituents). A single modeling run was done using the standardized emission rate of 1 gram/second from each source. The resulting "unit" air concentrations were converted to HAP-specific air concentrations using the emission rate estimates for each HAP (see Tables in Appendix C for these emission rates). Cancer risk estimates or hazard quotients were then calculated based on the HAP-specific estimated air concentrations. For screening purposes, each HAP maximum air concentration was assumed to impact the same receptor and cancer risks and hazards were calculated accordingly. It is anticipated that this maximum, facility risk or hazard would be lower after the refined level of analysis.

Table A-2. Screening Analysis Cancer Risk Results by Source at AK Steel Middletown

“Coke Oven Emissions” and Constituent HAPs	**Coke Oven Emission Points Across Coke Facility**								
	Battery Charging	**Battery Doors**	**Battery Lids**	**Battery Offtake**	**Pushing**	**Quenching**	**Combustion Stack**[1]	**Pushing Control Device**	**By-Product Plant**
Benzo(a)pyrene							$2x10^{-10}$		
Benzo(a)anthracene							$1x10^{-11}$	$2x10^{-10}$	
Benzene								$9x10^{-9}$	$2x10^{-5}$
Benzene soluble organics	$2x10^{-6}$	$2x10^{-5}$	$4x10^{-7}$	$1x10^{-6}$	$2x10^{-5}$	$4x10^{-6}$			
Benzo(b)fluoranthene							$4x10^{-11}$	$2x10^{-10}$	
Benzo(k)fluoranthene							$2x10^{-13}$	$1x10^{-10}$	
Chrysene							$6x10^{-12}$	$5x10^{-11}$	
Nickel							$6x10^{-10}$	$2x10^{-9}$	
Arsenic							$2x10^{-8}$	$1x10^{-8}$	
Beryllium							$1x10^{-10}$	$4x10^{-10}$	
Cadmium							$8x10^{-10}$	$1x10^{-9}$	
Aggregate risk across each source	**$2x10^{-6}$**	**$2x10^{-5}$**	**$4x10^{-7}$**	**$1x10^{-6}$**	**$2x10^{-5}$**	**$4x10^{-6}$**	**$2x10^{-8}$**	**$2x10^{-8}$**	**$2x10^{-5}$**
Total risk from facility									**$7x10^{-5}$**

[1] Combustion stack emissions come from the burning of the fuel used to heat the coke ovens. Coke batteries usually have a single stack per battery, therefore, AK-Steel in Ashland has 2 combustion stacks. Erie coke also has two batteries but it has only one stack that is shared by its two batteries.

Table A-3. Screening Analysis Cancer Risk Results by Source at AK Steel Ashland

"Coke Oven Emissions" and Constituent HAPs	Coke Oven Emission Points Across Coke Facility								
	Battery Charging	Battery Doors	Battery Lids	Battery Offtake	Pushing	Quenching	Combustion Stack[1]	Pushing Control Device	By-Product Plant
Benzo(a)pyrene							4×10^{-9}		
Benzo(a)anthracene							2×10^{-10}	4×10^{-9}	
Benzene								2×10^{-7}	5×10^{-4}
Benzene soluble organics	2×10^{-5}	2×10^{-4}	5×10^{-6}	1×10^{-5}	3×10^{-4}	2×10^{-4}			
Benzo(b)fluoranthene							7×10^{-10}	3×10^{-9}	
Benzo(k)fluoranthene							3×10^{-12}	2×10^{-9}	
Chrysene							1×10^{-10}	1×10^{-9}	
Nickel							1×10^{-8}	3×10^{-8}	
Arsenic							4×10^{-7}	2×10^{-7}	
Beryllium							2×10^{-9}	8×10^{-9}	
Cadmium							1×10^{-8}	2×10^{-8}	
Aggregate risk across each source	**2×10^{-5}**	**2×10^{-4}**	**5×10^{-6}**	**1×10^{-5}**	**3×10^{-4}**	**2×10^{-4}**	**4×10^{-7}**	**5×10^{-7}**	**5×10^{-4}**
Total risk from facility									**1×10^{-3}**

[1] Combustion stack emissions come from the burning of the fuel used to heat the coke ovens. Coke batteries usually have a single stack per battery, therefore, AK-Steel in Ashland has 2 combustion stacks. Erie coke also has two batteries but it has only one stack that is shared by its two batteries.

Table A-4. Screening Analysis Cancer Risk Results by Source at Erie Coke

“Coke Oven Emissions” and Constituent HAPs	Coke Oven Emission Points Across Coke Facility								
	Battery Charging	**Battery Doors**	**Battery Lids**	**Battery Offtake**	**Pushing**	**Quenching**	**Combustion Stack[1]**	**Pushing Control Device**	**By-Product Plant**
Benzo(a)pyrene							$2x10^{-10}$		
Benzo(a)anthracene							$1x10^{-11}$	$3x10^{-10}$	
Benzene								$1x10^{-8}$	$7x10^{-6}$
Benzene soluble organics	$5x10^{-6}$	$8x10^{-5}$	$2x10^{-6}$	$2x10^{-6}$	$7x10^{-5}$	$5x10^{-6}$			
Benzo(b)fluoranthene							$3x10^{-11}$	$2x10^{-10}$	
Benzo(k)fluoranthene							$1x10^{-13}$	$2x10^{-10}$	
Chrysene							$4x10^{-12}$	$7x10^{-11}$	
Nickel							$4x10^{-10}$	$2x10^{-9}$	
Arsenic							$2x10^{-8}$	$2x10^{-8}$	
Beryllium							$8x10^{-11}$	$5x10^{-10}$	
Cadmium							$6x10^{-10}$	$2x10^{-9}$	
Aggregate risk across each source	$5x10^{-6}$	$8x10^{-5}$	$2x10^{-6}$	$2x10^{-6}$	$7x10^{-5}$	$5x10^{-6}$	$2x10^{-8}$	$3x10^{-8}$	$7x10^{-6}$
Total risk from facility									$2x10^{-4}$

[1] Combustion stack emissions come from the burning of the fuel used to heat the coke ovens. Coke batteries usually have a single stack per battery, therefore, AK-Steel in Ashland has 2 combustion stacks. Erie coke also has two batteries but it has only one stack that is shared by its two batteries.

Table A-5. Screening Analysis Cancer Risk Results by Source at Tonawanda

"Coke Oven Emissions" and Constituent HAPs	**Coke Oven Emission Points Across Coke Facility**								
	Battery Charging	**Battery Doors**	**Battery Lids**	**Battery Offtake**	**Pushing**	**Quenching**	**Combustion Stack**[1]	**Pushing Control Device**	**By-Product Plant**
Benzo(a)pyrene							2x10^{-10}		
Benzo(a)anthracene							2x10^{-11}		
Benzene									5x10^{-5}
Benzene soluble organics	3x10^{-6}	5x10^{-5}	9x10^{-7}	2x10^{-6}	5x10^{-5}	6x10^{-6}			
Benzo(b)fluoranthene							4x10^{-11}		
Benzo(k)fluoranthene							2x10^{-13}		
Chrysene							6x10^{-12}		
Nickel							6x10^{-10}		
Arsenic							2x10^{-8}		
Beryllium							1x10^{-10}		
Cadmium							9x10^{-10}		
Aggregate risk across each source	**3x10^{-6}**	**5x10^{-5}**	**9x10^{-7}**	**2x10^{-6}**	**5x10^{-5}**	**6x10^{-6}**	**3x10^{-8}**		**5x10^{-5}**
Total risk from facility									**2x10^{-4}**

[1] Combustion stack emissions come from the burning of the fuel used to heat the coke ovens. Coke batteries usually have a single stack per battery, therefore, AK-Steel in Ashland has 2 combustion stacks. Erie coke also has two batteries but it has only one stack that is shared by its two batteries.

Table A-6. Noncancer Screening Results (Hazard Quotients) for AK Steel Middletown [1]

Constituent	Battery Charging	Battery Doors	Battery Lids	Battery Offtake	Pushing	Quenching	Combustion Stack	Pushing Control Device	By-product
Benzene	$4x10^{-5}$	$6x10^{-4}$	$1x10^{-5}$	$4x10^{-5}$				$4x10^{-5}$	$6x10^{-2}$
Hydrocyanic acid	$5x10^{-5}$	$5x10^{-4}$	$1x10^{-5}$	$4x10^{-5}$					
Carbon disulfide	$4x10^{-9}$	$5x10^{-8}$	$9x10^{-10}$	$3x10^{-9}$					
Naphthalene	$1x10^{-4}$	$1x10^{-3}$	$2x10^{-5}$	$8x10^{-5}$	$4x10^{-4}$	$8x10^{-5}$	$4x10^{-5}$	$2x10^{-4}$	
Cresol, o-	$3x10^{-10}$	$4x10^{-9}$	$8x10^{-11}$	$3x10^{-10}$					
Cumene	$2x10^{-8}$	$2x10^{-7}$	$5x10^{-9}$	$2x10^{-8}$					
Cresol, p-	$9x10^{-10}$	$1x10^{-8}$	$2x10^{-10}$	$7x10^{-10}$					
1,3-Butadiene	$1x10^{-5}$	$1x10^{-4}$	$3x10^{-6}$	$1x10^{-5}$					
Toluene	$3x10^{-7}$	$3x10^{-6}$	$6x10^{-8}$	$2x10^{-7}$					$3x10^{-4}$
Phenol	$8x10^{-9}$	$1x10^{-7}$	$2x10^{-9}$	$6x10^{-9}$					
Xylene (mixed isomers)	$3x10^{-8}$	$4x10^{-7}$	$7x10^{-9}$	$2x10^{-8}$					$1x10^{-4}$
Lead					$4x10^{-4}$	$8x10^{-5}$	$6x10^{-6}$	$8x10^{-6}$	
Manganese					$4x10^{-3}$	$7x10^{-4}$	$1x10^{-4}$	$6x10^{-4}$	
Nickel					$2x10^{-3}$	$4x10^{-4}$	$1x10^{-5}$	$3x10^{-5}$	
Antimony					$8x10^{-5}$	$2x10^{-5}$			
Arsenic	$2x10^{-8}$	$2x10^{-7}$	$4x10^{-9}$	$1x10^{-8}$	$1x10^{-2}$	$2x10^{-3}$	$2x10^{-4}$	$9x10^{-5}$	
Beryllium					$2x10^{-4}$	$5x10^{-5}$	$2x10^{-6}$	$9x10^{-6}$	
Cadmium					$9x10^{-4}$	$2x10^{-4}$	$2x10^{-5}$	$3x10^{-5}$	
Cobalt					$2x10^{-4}$	$3x10^{-5}$			

Table A-6. Noncancer Screening Results (Hazard Quotients) for AK Steel Middletown [1]

Constituent	Battery Charging	Battery Doors	Battery Lids	Battery Offtake	Pushing	Quenching	Combustion Stack	Pushing Control Device	By-product
Hydrochloric acid	$1x10^{-7}$	$1x10^{-6}$	$3x10^{-8}$	$1x10^{-7}$					
Hydrofluoric acid	$5x10^{-10}$	$5x10^{-9}$	$1x10^{-10}$	$4x10^{-10}$					
Phosphorus							$5x10^{-4}$	$2x10^{-3}$	
Selenium	$3x10^{-11}$	$3x10^{-10}$	$6x10^{-12}$	$2x10^{-11}$	$4x10^{-6}$	$8x10^{-7}$	$2x10^{-7}$	$7x10^{-8}$	
Total	**$2x10^{-4}$**	**$2x10^{-3}$**	**$5x10^{-5}$**	**$1x10^{-4}$**	**$2x10^{-2}$**	**$4x10^{-3}$**	**$9x10^{-4}$**	**$3x10^{-3}$**	**$6x10^{-2}$**

[1] The results are for constituents of the HAP, coke oven emission, for which noncancer values exist. Results for the HAP, coke oven emissions, are not included because no noncancer value exists. Each HAP/source value is a hazard quotient. The "Total" results present the hazard index (HI) for each source emitting that collection of HAPs and does not consider the target organ. The aggregate, facility level hazard quotients for each HAP and the facility level hazard index are presented in Table 3-2, titled, "Summary of Noncancer Risk Assessment Screening Analysis" found in section 3. The aggregate HQs and HIs assume that the receptor is at the same location for all HAP impacts. It is anticipated that this maximum, facility hazard would be lower for HAPs assessed in a refined level of analysis.

Table A-7. Noncancer Screening Results (Hazard Quotient) for AK Steel Ashland [1]

Constituent	Battery Charging	Battery Doors	Battery Lids	Battery Offtakes	Pushing	Quenching	Combustion stack	Pushing Control Device	By-Product
Benzene	$6x10^{-4}$	$6x10^{-3}$	$1x10^{-4}$	$2x10^{-4}$				$8x10^{-4}$	2
Hydrocyanic acid	$6x10^{-4}$	$6x10^{-3}$	$1x10^{-4}$	$3x10^{-4}$					
Carbon disulfide	$5x10^{-8}$	$5x10^{-7}$	$1x10^{-8}$	$2x10^{-8}$					
Naphthalene	$1x10^{-3}$	$1x10^{-2}$	$3x10^{-4}$	$6x10^{-4}$	$6x10^{-3}$	$3x10^{-3}$	$7x10^{-4}$	$5x10^{-3}$	
Cresol, o-	$4x10^{-9}$	$4x10^{-8}$	$9x10^{-10}$	$2x10^{-9}$					
Cumene	$3x10^{-7}$	$3x10^{-6}$	$6x10^{-8}$	$1x10^{-7}$					
Cresol, p-	$1x10^{-8}$	$1x10^{-7}$	$3x10^{-9}$	$6x10^{-9}$					
1,3-Butadiene	$2x10^{-4}$	$2x10^{-3}$	$3x10^{-5}$	$8x10^{-5}$					
Toluene	$4x10^{-6}$	$4x10^{-5}$	$8x10^{-7}$	$2x10^{-6}$					$1x10^{-2}$
Phenol	$1x10^{-7}$	$1x10^{-6}$	$2x10^{-8}$	$5x10^{-8}$					
Xylene (mixed isomers)	$4x10^{-7}$	$4x10^{-6}$	$9x10^{-8}$	$2x10^{-7}$					$5x10^{-3}$
Lead					$6x10^{-3}$	$3x10^{-3}$	$1x10^{-4}$	$2x10^{-4}$	
Manganese					$6x10^{-2}$	$3x10^{-2}$	$2x10^{-3}$	$1x10^{-2}$	
Nickel					$3x10^{-2}$	$1x10^{-2}$	$2x10^{-4}$	$7x10^{-4}$	
Antimony					$1x10^{-3}$	$6x10^{-4}$			
Arsenic	$2x10^{-7}$	$3x10^{-6}$	$5x10^{-8}$	$1x10^{-7}$	$2x10^{-1}$	$8x10^{-2}$	$3x10^{-3}$	$2x10^{-3}$	
Beryllium					$4x10^{-3}$	$2x10^{-3}$	$4x10^{-5}$	$2x10^{-4}$	
Cadmium					$1x10^{-2}$	$7x10^{-3}$	$4x10^{-4}$	$6x10^{-4}$	
Cobalt					$3x10^{-3}$	$1x10^{-3}$			
Hydrochloric acid	$2x10^{-6}$	$2x10^{-5}$	$3x10^{-7}$	$8x10^{-7}$					

Table A-7. Noncancer Screening Results (Hazard Quotient) for AK Steel Ashland [1]

Constituent	Battery Charging	Battery Doors	Battery Lids	Battery Offtakes	Pushing	Quenching	Combustion stack	Pushing Control Device	By-Product
Hydrofluoric acid	$6x10^{-9}$	$6x10^{-8}$	$1x10^{-9}$	$3x10^{-9}$					
Phosphorus							$8x10^{-3}$	$3x10^{-2}$	
Selenium	$4x10^{-10}$	$4x10^{-9}$	$8x10^{-11}$	$2x10^{-10}$	$6x10^{-5}$	$3x10^{-5}$	$4x10^{-6}$	$1x10^{-6}$	
Total	**$2x10^{-3}$**	**$2x10^{-2}$**	**$6x10^{-4}$**	**$1x10^{-3}$**	**$3x10^{-1}$**	**$1x10^{-1}$**	**$1x10^{-2}$**	**$5x10^{-2}$**	**2**

[1] The results are for constituents of the HAP, coke oven emission, for which noncancer values exist. Results for the HAP, coke oven emissions, are not included because no noncancer value exists. Each HAP/source value is a hazard quotient. The "Total" results present the hazard index (HI) for each source emitting that collection of HAPs and does not consider the target organ. The aggregate, facility level hazard quotients for each HAP and the facility level hazard index are presented in Table 3-2, titled, "Summary of Noncancer Risk Assessment Screening Analysis" found in section 3. The aggregate HQs and HIs assume that the receptor is at the same location for all HAP impacts. It is anticipated that this maximum, facility hazard would be lower for any HAP assessed in a refined level of analysis.

Table A.-8. Noncancer Screening Results (Hazard Quotient) for Erie Coke [1]

Constituent	Battery Charging	Battery Doors	Battery Lids	Battery Offtake	Pushing	Quenching	Combustion Stack	Pushing Control Device	By-Product
Benzene	$1x10^{-4}$	$2x10^{-3}$	$6x10^{-5}$	$6x10^{-5}$				$6x10^{-5}$	$4x10^{-2}$
Hydrocyanic acid	$1x10^{-4}$	$2x10^{-3}$	$6x10^{-5}$	$6x10^{-5}$					
Carbon disulfide	$1x10^{-8}$	$2x10^{-7}$	$5x10^{-9}$	$5x10^{-9}$					
Naphthalene	$3x10^{-4}$	$5x10^{-3}$	$1x10^{-4}$	$1x10^{-4}$	$1x10^{-3}$	$8x10^{-5}$	$3x10^{-5}$	$3x10^{-4}$	
Cresol, o-	$9x10^{-10}$	$2x10^{-8}$	$4x10^{-10}$	$4x10^{-10}$					
Cumene	$6x10^{-8}$	$1x10^{-6}$	$3x10^{-8}$	$3x10^{-8}$					
Cresol, p-	$3x10^{-9}$	$4x10^{-8}$	$1x10^{-9}$	$1x10^{-9}$					
1,3-Butadiene	$3x10^{-5}$	$6x10^{-4}$	$2x10^{-5}$	$2x10^{-5}$					
Toluene	$8x10^{-7}$	$1x10^{-5}$	$4x10^{-7}$	$4x10^{-7}$					$1x10^{-4}$
Phenol	$2x10^{-8}$	$4x10^{-7}$	$1x10^{-8}$	$1x10^{-8}$					
Xylene (mixed isomers)	$9x10^{-8}$	$2x10^{-6}$	$4x10^{-8}$	$4x10^{-8}$					$6x10^{-5}$
Lead					$1x10^{-3}$	$8x10^{-5}$	$4x10^{-6}$	$1x10^{-5}$	
Manganese					$1x10^{-2}$	$8x10^{-4}$	$8x10^{-5}$	$8x10^{-4}$	
Nickel					$6x10^{-3}$	$4x10^{-4}$	$8x10^{-6}$	$5x10^{-5}$	
Antimony					$3x10^{-4}$	$2x10^{-5}$			
Arsenic	$5x10^{-8}$	$9x10^{-7}$	$2x10^{-8}$	$3x10^{-8}$	$4x10^{-2}$	$2x10^{-3}$	$1x10^{-4}$	$1x10^{-4}$	
Beryllium					$7x10^{-4}$	$5x10^{-5}$	$2x10^{-6}$	$1x10^{-5}$	
Cadmium					$3x10^{-3}$	$2x10^{-4}$	$2x10^{-5}$	$4x10^{-5}$	
Cobalt					$5x10^{-4}$	$4x10^{-5}$			
Hydrochloric acid	$3x10^{-7}$	$6x10^{-6}$	$2x10^{-7}$	$2x10^{-7}$					

Table A.-8. Noncancer Screening Results (Hazard Quotient) for Erie Coke [1]

Constituent	Battery Charging	Battery Doors	Battery Lids	Battery Offtake	Pushing	Quenching	Combustion Stack	Pushing Control Device	By-Product
Hydrofluoric acid	$1x10^{-9}$	$2x10^{-8}$	$6x10^{-10}$	$6x10^{-10}$					
Phosphorus							$3x10^{-4}$	$2x10^{-3}$	
Selenium	$8x10^{-11}$	$1x10^{-9}$	$4x10^{-11}$	$4x10^{-11}$	$1x10^{-5}$	$8x10^{-7}$	$2x10^{-7}$	$9x10^{-8}$	
Total	**$6x10^{-4}$**	**$9x10^{-3}$**	**$2x10^{-4}$**	**$2x10^{-4}$**	**$6x10^{-2}$**	**$4x10^{-3}$**	**$5x10^{-4}$**	**$3x10^{-3}$**	**$4x10^{-2}$**

[1] The results are for constituents of the HAP, coke oven emission, for which noncancer values exist. Results for the HAP, coke oven emissions, are not included because no noncancer value exists. Each HAP/source value is a hazard quotient. The “Total” results present the hazard index (HI) for each source emitting that collection of HAPs and does not consider the target organ. The aggregate, facility level hazard quotients for each HAP and the facility level hazard index are presented in Table 3-2, titled, “Summary of Noncancer Risk Assessment Screening Analysis” found in section 3. The aggregate HQs and HIs assume that the receptor is at the same location for all HAP impacts. It is anticipated that this maximum, facility hazard would be lower for any HAP assessed in a refined level of analysis.

Table A-9. Noncancer Screening Results (Hazard Quotient) for Tonawanda [1]

Constituent	Battery Charging	Battery Doors	Battery Lids	Battery Offtake	Pushing	Quenching	Combustion Stack	Pushing Control Device	By-Product
Benzene	$8x10^{-5}$	$1x10^{-3}$	$2x10^{-5}$	$4x10^{-5}$					$2x10^{-1}$
Hydrocyanic acid	$7x10^{-5}$	$1x10^{-3}$	$3x10^{-5}$	$4x10^{-5}$					
Carbon disulfide	$6x10^{-9}$	$1x10^{-7}$	$2x10^{-9}$	$4x10^{-9}$					
Naphthalene	$2x10^{-4}$	$3x10^{-3}$	$5x10^{-5}$	$9x10^{-5}$	$1x10^{-3}$	$1x10^{-4}$	$5x10^{-5}$		
Cresol, o-	$5x10^{-10}$	$9x10^{-9}$	$2x10^{-10}$	$3x10^{-10}$					
Cumene	$3x10^{-8}$	$6x10^{-7}$	$1x10^{-8}$	$2x10^{-8}$					
Cresol, p-	$1x10^{-9}$	$3x10^{-8}$	$5x10^{-10}$	$9x10^{-10}$					
1,3-Butadiene	$2x10^{-5}$	$3x10^{-4}$	$7x10^{-6}$	$1x10^{-5}$					
Toluene	$4x10^{-7}$	$8x10^{-6}$	$2x10^{-7}$	$3x10^{-7}$					$1x10^{-3}$
Phenol	$1x10^{-8}$	$2x10^{-7}$	$5x10^{-9}$	$8x10^{-9}$					
Xylene (mixed isomers)	$5x10^{-8}$	$9x10^{-7}$	$2x10^{-8}$	$3x10^{-8}$					$4x10^{-4}$
Lead					$9x10^{-4}$	$1x10^{-4}$	$6x10^{-6}$		
Manganese					$9x10^{-3}$	$9x10^{-4}$	$1x10^{-4}$		
Nickel					$4x10^{-3}$	$4x10^{-4}$	$1x10^{-5}$		
Antimony					$2x10^{-4}$	$2x10^{-5}$			
Arsenic	$3x10^{-8}$	$5x10^{-7}$	$1x10^{-8}$	$2x10^{-8}$	$3x10^{-2}$	$3x10^{-3}$	$2x10^{-4}$		
Beryllium					$6x10^{-4}$	$6x10^{-5}$	$3x10^{-6}$		
Cadmium					$2x10^{-3}$	$2x10^{-4}$	$2x10^{-5}$		
Cobalt					$4x10^{-4}$	$4x10^{-5}$			

Table A-9. Noncancer Screening Results (Hazard Quotient) for Tonawanda [1]

Constituent	Battery Charging	Battery Doors	Battery Lids	Battery Offtake	Pushing	Quenching	Combustion Stack	Pushing Control Device	By-Product
Hydrochloric acid	2x10^{-7}	3x10^{-6}	7x10^{-8}	1x10^{-7}					
Hydrofluoric acid	7x10^{-10}	1x10^{-8}	3x10^{-10}	4x10^{-10}					
Phosphorus							5x10^{-4}		
Selenium	4x10^{-11}	8x10^{-10}	2x10^{-11}	3x10^{-11}	1x10^{-5}	1x10^{-6}	2x10^{-7}		
Total	**3x10^{-4}**	**5x10^{-3}**	**1x10^{-4}**	**2x10^{-4}**	**5x10^{-2}**	**5x10^{-3}**	**9x10^{-4}**		**2x10^{-1}**

[1] The results are for constituents of the HAP, coke oven emission, for which noncancer values exist. Results for the HAP, coke oven emissions, are not included because no noncancer value exists. Each HAP/source value is a hazard quotient. The "Total" results present the hazard index (HI) for each source emitting that collection of HAPs and does not consider the target organ. The aggregate, facility level hazard quotients for each HAP and the facility level hazard index are presented in Table 3-2, titled, "Summary of Noncancer Risk Assessment Screening Analysis" found in section 3. The aggregate HQs and HIs assume that the receptor is at the same location for all HAP impacts. It is anticipated that this maximum, facility hazard would be lower for any HAP assessed in a refined level of analysis.

Multipathway Screening Analysis

The multipathway screening analysis for coke oven batteries was done to determine the relative magnitude of risks due to routes of exposure other than inhalation and from the different HAPs emitted from coke ovens batteries. This analysis included ingestion of contaminated food or soil, and drinking water and takes into account the potential for HAPs to accumulate in the food chain (bioaccumulate) and persist in the environment. The Tables that follow in this section contain information that was used in this analysis.

For the multipathway analysis, the air concentration and deposition estimates from the ISCST3 model were used as inputs (Table A-10) to the Indirect Exposure Model Version 2M (IEM-2M). IEM-2M is a spreadsheet model developed for the *Mercury Study Report to Congress* (US EPA, 1997), which uses a calculation approach similar to the *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (US EPA, 1998). The model was used to address multiple pollutants under a case study residual risk assessment on secondary lead smelters and was reviewed by EPA's science advisory board (U.S.EPA, 2000). In addition to air pollutant concentrations and deposition rates, the IEM-2M model requires a wide array of inputs on human exposure factors, and transfer and accumulation factors for pollutants in various environmental media and animal groups (Tables A-11 to A-18).

Blood Lead Level Analysis

The inhalation rate, water consumption rate, and the amount of soil/dust ingested daily were entered into IEUBK model by age group. The central tendency and 90th percentile exposure values from the Exposure Factor Handbook were used and are presented in Tables A-29 and A-30.

Dietary intake of lead is another input to the IEUBK model, which depends both on the concentration of lead in food and the consumption rate of the food. The consumption rate also depends on the weight of the child. The lead concentration in each of several food types was obtained from IEM-2M modeling. These values, for each food type and for each age range, were multiplied by the consumption rate and body weight, and then summed for all foods by age range. Tables A-19 to A-30 present the information used in this assessment.

The outdoor air lead concentration, the lead concentration in drinking water, and the soil lead level are three additional values that can be input to IEUBK. The value for the outdoor air lead concentration was obtained from ISCST3 and was assumed to remain constant over all age ranges. The values for lead concentration in drinking water and outdoor soil lead levels were obtained from ISCST3 and IEM-2M modeling and were assumed to remain constant over all age ranges. In addition, the indoor dust level was assumed to equal the outdoor soil level for all age ranges and IEUBK default values for time spent outdoors were used. The concentration values are outputs from IEM-2M. The absorption and other values are best estimate values that are used within IEUBK as defaults.

Table A-10. Air Concentration and Deposition Rate Inputs for Multipathway Screening Assessment

Input Type	HAP	AK Steel - Ashland		AK Steel - Middletown		Erie Coke		Tonawanda	
		WB/WS[1] Values	Receptor Values	WB/WS[1] Values	Receptor Values	WB/WS[1] Values	Receptor Values	WB/WS[1] Values	Receptor Values
Air Concentration (Vapor) (ug/m^3)	Acenaphthene	7.6x10^{-5}	5.9x10^{-5}	2.7x10^{-5}	1.4x10^{-5}	1.3x10^{-6}	2.8x10^{-6}	1.9x10^{-5}	9.6x10^{-6}
	Anthracene	9.2x10^{-5}	7.1x10^{-5}	3.3x10^{-5}	1.7x10^{-5}	4.2x10^{-7}	6.9x10^{-7}	1.3x10^{-5}	5.1x10^{-6}
	Benzo(a)anthracene	2.4x10^{-4}	1.9x10^{-4}	1.2x10^{-4}	6.5x10^{-5}	2.6x10^{-6}	4.2x10^{-6}	6.9x10^{-5}	2.5x10^{-5}
	Benzo(a)pyrene	1.0x10^{-4}	7.7x10^{-5}	5.2x10^{-5}	2.9x10^{-5}	1.2x10^{-6}	1.9x10^{-6}	3.0x10^{-5}	1.1x10^{-5}
	Benzo(b)fluoranthene	1.8x10^{-4}	1.4x10^{-4}	8.5x10^{-5}	4.7x10^{-5}	1.9x10^{-6}	3.1x10^{-6}	5.0x10^{-5}	1.8x10^{-5}
	Benzo(k)fluoranthene	2.5x10^{-5}	2.0x10^{-5}	1.3x10^{-5}	6.9x10^{-6}	2.8x10^{-7}	4.5x10^{-7}	7.4x10^{-6}	2.7x10^{-6}
	Chrysene	2.8x10^{-4}	2.2x10^{-4}	1.3x10^{-4}	7.3x10^{-5}	2.9x10^{-6}	4.7x10^{-6}	7.8x10^{-5}	2.9x10^{-5}
	Fluoranthene	7.6x10^{-4}	5.8x10^{-4}	3.6x10^{-4}	2.0x10^{-4}	7.4x10^{-6}	1.2x10^{-5}	2.0x10^{-4}	7.5x10^{-5}
	Fluorene	3.6x10^{-4}	2.8x10^{-4}	1.7x10^{-4}	9.3x10^{-5}	3.4x10^{-6}	5.6x10^{-6}	8.8x10^{-5}	3.2x10^{-5}
	Indeno(1,2,3-cd) pyrene	8.7x10^{-7}	6.8x10^{-7}	4.1x10^{-7}	2.3x10^{-7}	8.9x10^{-9}	1.5x10^{-8}	2.4x10^{-7}	8.9x10^{-8}
	Pyrene	1.5x10^{-4}	1.1x10^{-4}	7.0x10^{-5}	3.9x10^{-5}	1.5x10^{-6}	2.5x10^{-6}	3.9x10^{-5}	1.4x10^{-5}
	Cadmium	0	0	0	0	0	0	0	0
Dry Deposition (Particulate) (g/m^2-yr)	Acenaphthene	0	0	0	0	0	0	0	0
	Anthracene	0	0	0	0	0	0	0	0
	Benzo(a)anthracene	6.3x10^{-6}	4.0x10^{-6}	2.8x10^{-6}	1.0x10^{-6}	1.4x10^{-7}	2.0x10^{-7}	3.4x10^{-6}	7.2x10^{-7}
	Benzo(a)pyrene	2.1x10^{-5}	1.3x10^{-5}	1.0x10^{-5}	3.7x10^{-6}	5.3x10^{-7}	7.5x10^{-7}	1.2x10^{-5}	2.5x10^{-6}
	Benzo(b)fluoranthene	7.5x10^{-6}	4.7x10^{-6}	3.3x10^{-6}	1.2x10^{-6}	1.7x10^{-7}	2.4x10^{-7}	4.0x10^{-6}	8.4x10^{-7}
	Benzo(k)fluroanthene	2.8x10^{-5}	1.8x10^{-5}	1.3x10^{-5}	4.7x10^{-6}	6.5x10^{-7}	9.3x10^{-7}	1.6x10^{-5}	3.2x10^{-6}
	Chrysene	1.7x10^{-5}	1.1x10^{-5}	7.5x10^{-6}	2.8x10^{-6}	3.7x10^{-7}	5.3x10^{-7}	9.1x10^{-6}	1.9x10^{-6}
	Fluoranthene	1.2x10^{-6}	7.3x10^{-7}	5.1x10^{-7}	1.9x10^{-7}	2.5x10^{-8}	3.5x10^{-8}	6.1x10^{-7}	1.3x10^{-7}
	Fluorene	4.8x10^{-6}	2.9x10^{-6}	2.1x10^{-6}	7.6x10^{-7}	9.7x10^{-8}	1.4x10^{-7}	2.3x10^{-6}	4.7x10^{-7}
	Indeno(1,2,3-cd) pyrene	2.4x10^{-5}	1.5x10^{-5}	1.0x10^{-5}	3.8x10^{-6}	5.2x10^{-7}	7.4x10^{-7}	1.3x10^{-5}	2.7x10^{-6}
	Pyrene	1.2x10^{-4}	7.1x10^{-5}	5.1x10^{-5}	1.9x10^{-5}	2.6x10^{-6}	3.7x10^{-6}	6.0x10^{-5}	1.2x10^{-5}
	Cadmium	4.6x10^{-6}	2.9x10^{-6}	1.4x10^{-6}	5.1x10^{-7}	5.9x10^{-8}	8.4x10^{-8}	1.8x10^{-6}	4.0x10^{-7}
Wet Deposition (Vapor and Particulate) (g/m^2-yr)	Acenaphthene	6.3x10^{-6}	4.3x10^{-6}	2.5x10^{-6}	2.6x10^{-6}	2.4x10^{-7}	2.4x10^{-7}	6.1x10^{-6}	6.3x10^{-6}
	Anthracene	7.4x10^{-6}	5.1x10^{-6}	2.9x10^{-6}	3.0x10^{-6}	5.4x10^{-8}	5.5x10^{-8}	1.3x10^{-6}	1.3x10^{-6}
	Benzo(a)anthracene	1.9x10^{-5}	1.2x10^{-5}	9.2x10^{-6}	9.9x10^{-6}	3.5x10^{-7}	3.5x10^{-7}	5.8x10^{-6}	5.7x10^{-6}
	Benzo(a)pyrene	1.1x10^{-5}	6.7x10^{-6}	5.4x10^{-6}	5.8x10^{-6}	2.2x10^{-7}	2.3x10^{-7}	3.5x10^{-6}	3.4x10^{-6}
	Benzo(b)fluoranthene	1.5x10^{-5}	9.7x10^{-6}	7.1x10^{-6}	7.6x10^{-6}	2.6x10^{-7}	2.7x10^{-7}	4.5x10^{-6}	4.4x10^{-6}
	Benzo(k)fluoranthene	6.7x10^{-6}	4.3x10^{-6}	3.3x10^{-6}	3.5x10^{-6}	1.3x10^{-7}	1.3x10^{-7}	2.1x10^{-6}	2.0x10^{-6}
	Chrysene	2.5x10^{-5}	1.6x10^{-5}	1.2x10^{-5}	1.2x10^{-5}	4.2x10^{-7}	4.3x10 $^{-7}$	7.3 x10^{-6}	7.1x10^{-6}
	Fluoranthene	6.0x10^{-5}	3.9x10^{-5}	2.9x10^{-5}	3.1x10^{-5}	9.6x10^{-7}	9.8x10^{-7}	1.8x10^{-5}	1.7x10^{-5}
	Fluorene	2.7x10^{-5}	1.7x10^{-5}	1.3x10^{-5}	1.4x10^{-5}	4.5x10^{-7}	4.6x10^{-7}	7.3x10^{-6}	7.2x10^{-6}
	Indeno(1,2,3-cd) pyrene	4.4x10^{-6}	2.8x10^{-6}	2.0x10^{-6}	2.2x10^{-6}	7.3x10^{-8}	7.5x10^{-8}	1.3x10^{-6}	1.3x10^{-6}
	Pyrene	3.2x10^{-5}	2.0x10^{-5}	1.5x10^{-5}	1.7x10^{-5}	5.6x10^{-7}	5.7x10^{-7}	9.5x10^{-6}	9.3x10^{-6}
	Cadmium	1.1x10^{-6}	7.3x10^{-7}	4.2x10^{-7}	4.4x10^{-7}	8.4x10^{-9}	8.6x10^{-9}	2.3x10^{-7}	2.3x10^{-7}
Air Concentration (Vapor and Particulate) (ug/m^3)	Acenaphthene	7.6x10^{-5}	5.9x10^{-5}	2.7x10^{-5}	1.4x10^{-5}	1.3x10^{-6}	2.8x10^{-6}	1.9x10^{-5}	9.6x10^{-6}
	Anthracene	9.2x10^{-5}	7.1x10^{-5}	3.3x10^{-5}	1.7x10^{-5}	4.2x10^{-7}	6.9x10^{-7}	1.3x10^{-5}	5.1x10^{-6}
	Benzo(a)anthracene	2.7x10^{-4}	2.1x10^{-4}	1.3x10^{-4}	7.3x10^{-5}	2.9x10^{-6}	4.8x10^{-6}	7.8x10^{-5}	2.9x10^{-5}
	Benzo(a)pyrene	2.1x10^{-4}	1.6x10^{-4}	1.1x10^{-4}	6.0x10^{-5}	2.4x10^{-6}	4.0x10^{-6}	6.4x10^{-5}	2.3x10^{-5}
	Benzo(b)fluoranthene	2.2x10^{-4}	1.7x10^{-4}	1.0x10^{-4}	5.7x10^{-5}	2.3x10^{-6}	3.7x10^{-6}	6.1x10^{-5}	2.2x10^{-5}
	Benzo(k)fluoranthene	1.7x10^{-4}	1.3x10^{-4}	8.4x10^{-5}	4.7X10^{-5}	1.9x10^{-6}	3.0x10^{-6}	4.9x10^{-5}	1.8x10^{-5}
	Chrysene	3.7x10^{-4}	2.9x10^{-4}	1.8x10^{-4}	9.6x10^{-5}	3.8x10^{-6}	6.2x10^{-6}	1.0x10^{-4}	3.8x10^{-5}
	Fluoranthene	7.6x10^{-4}	5.9x10^{-4}	3.6x10^{-4}	2.0x10^{-4}	7.5x10^{-6}	1.2x10^{-5}	2.1x10^{-4}	7.6x10^{-5}
	Fluorene	3.8x10^{-4}	3.0x10^{-4}	1.8x10^{-4}	1.0x10^{-4}	3.6x10^{-6}	6.0x10^{-6}	9.4x10^{-5}	3.4x10^{-5}
	Indeno(1,2,3-cd) pyrene	1.2x10^{-4}	9.7x10^{-5}	5.9x10^{-5}	3.2x10^{-5}	1.3x10^{-6}	2.1x10^{-6}	3.5x10^{-5}	1.3x10^{-5}
	Pyrene	7.4x10^{-4}	5.7x10^{-4}	3.6x10^{-4}	2.0x10^{-4}	7.7x10^{-6}	1.3x10^{-5}	2.0x10^{-4}	7.4x10^{-5}
	Cadmium	2.4x10^{-5}	1.8x10^{-5}	7.8x10^{-6}	4.1x10^{-6}	1.4x10^{-7}	2.4x10^{-7}	4.6x10^{-6}	1.9x10^{-6}

[1] WB/WS = Water body/Watershed Values

Table A-11. Model Inputs

Constants								
	RC: ideal gas constant (m^3-atm/mole-k)	$8.21x10^{-5}$						
	pa: air density (g/cm^3)	$1.19x10^{-3}$						
	ua: viscosity of air (g/cm-sec)	$1.84x10^{-4}$						
	Psed: solids density (kg/L or g/cm^3)	2.65						
:	Cdrag: drag coefficient	$1.10x10^{-3}$						
	kappa: Von Karman's coefficient	$4.00x10^{-1}$						
	lam2: boundary thickness (dimensionless)	4.00						
	Depth for base volatilization (m)	$5.00x10^{-3}$						
Agricultural	**Parameters**	Grains	Legumes	Root Vegetables	Fruits	Leafy Vegetables	Forage	Silage
	RP (interception fraction)[b]	0	0.008	0	0.05	0.15	0.47	0.44
	TP (Length of plant's exposure, yrs)	0.123	0.123	0.123	0.123	0.157	0.123	0.123
	YP (Yield of plant, kg dw/m^2)	0.3	0.104	0.334	0.107	0.177	0.31	0.84
	VG (Surface area volume to whole plant volume correction) for lipophilic (high k_{ow}) chemicals)	1	0.01	1	0.01	1	1	0.5
	VG (surface area volume to whole plant volume correction) for water soluble (low K_{ow}) chemicals	1	1	1	1	1	1	1
		Beef	Dairy	Pork				
	Grain consumption (kg/day)	0.47	2.6	3				
	Forage consumption (kg/day)	8.8	11	0				
	Silage consumption (kg/day)	2.5	3.3	1.3				
	Soil consumption (kg/day)	0.39	0.41	0.34				

[a] US Environmental Protection Agency, 1998. Methodology for Assessing Health Risks Associated With Multiple Pathways of Exposure to Combustor Emissions. EPA-600-R98-137. Office of Research and Development and National Center for Environmental Assessment, Cincinnati, OH.

[b] Interception fractions are zero for grains and root vegetables since they are considered "protected" vegetables. Direct deposition from air to the vegetables does not occur.

Table A-12. Default Site-Specific Dependent Parameters

Site-Dependent Parameters[a]	Default values used for each site
I (average annual irrigation, cm/yr)[b]	12.5
TA (average air temperature, C)[b]	11.9
TW (average water temperature, C)[b]	11.9
P (average annual precipitation, cm/yr)[b]	102
RO (average annual runoff, cm/yr)[b]	18
EV (average annual evapotranspiration, cm/yr)[b]	65
W (average wind speed, m/s)[b]	4.3
PS (Support practice factor)	1
SDEL (sediment delivery ration to water body)	0.2
EF (pollutant enrichment factor)	2
TC (time of concentration, yr)	30
BD (bulk soil density, g/cm^3)	1.4
ZD (depth of incorporation, cm; no tillage)	1
ZTILL (mixing depth for soil tillage, cm)	20
Theta (soil moisture content, L/L)	0.1
Theta_V (void space in soil, L/L)	0.2
CN (SCS soil curve number)	81.5
V (fraction of vegetative cover)	0.75
R (erosivity factor, /yr)	200
K (erodibility factor, tons/acre)	0.3
LS (topographic factor, unitless)	2.5
C (cover management factor, unitless)	0.006
SSW (suspended solids concentration, mg/L)	11
SSDEP (m/day)	0.5
v_ min: Mineralization for benthic solids (m/yr)	0.001
vs: Settling Velocity (m/yr)	730
vrs: Resuspension velocity (m/yr)	0.0037
E_sw: Pore water diffusion coefficient (m^2/yr)	0.158
v_sbio: Settling rate for biotic solids (m/yr)	73
L_sbio: Net internal production of biotic solids (g[solids]/m^2-	100
K_mort: Biotic mortality rate (/day)	0.03
BS: Benthic sediment concentration (kg/L)	0.075
DB (upper benthic depth, m)	0.02
BIO_P (aquatic plant biomass, mg/L)	2
BIO_F (total fish biomass, mg/L)	0.05
Bio_F_Tier3, mg/L	0.02

[A] Except where otherwise noted, U.S. Environmental Protection Agency, 1998. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Appendix C. EPA-530-D-98-001A, Office of Solid Waste and Emergency Response, Washington, D.C.

[B] Cincinnati site-dependent values from the Mercury Study: Report to Congress. U.S. Environmental Protection Agency, 1997. Office of Air Quality Planning and Standards, and Office of Research and Development, Research Triangle Park, North Carolina.

Table A-13. Central Tendency Exposure Factors

Exposure Parameter	Parameter Value		Source
BWa: Body Weight, adult aged 20-49 (kg)	71.8		EFH Table 7-11, recommended value
ED: Total exposure duration (yrs)	17.3		EFH Table 15-163, average total residence time for farm households
LT: Lifetime (yrs)	75.0		EFH p. 8-1, recommended value
Daily water ingestion rate (L/day)	1.4		EFH Table 3-30, mean value for adult
Water consumption rate (L/kg BW/d)	1.95×10^{-2}		Calculated: daily water ingestion rate (L/day)/body weight (kg)
CSA: soil ingestion rate (g/day)	5.00×10^{-2}		EFH Table 4-23, mean value for adults
CFAD: fish ingestion rate (g/kg/day)	1.39×10^{-1}		EFH Table 10-61, mean recreational fish intake for age 21-40
Plant consumption rates as consumed (G FW/kg BW/day)	Grains	3.1	
	Legumes	7.62×10^{-1}	
	Root vegetables	8.74×10^{-1}	
	Fruits	1.09	
	Leafy vegetables	1.05	
Plant consumption rates dry weight as used in model (g DW/kg BW/day)	Grains	2.77	Endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	1.47×10^{-1}	Percent mean moisture content, EFH Table 9-27
	Root vegetables	2.52×10^{-1}	Potatoes 71.2 percent mean moisture content, EFH Table 9-27
	Fruits	2.30×10^{-1}	Content, EFH Table 9-27
	Leafy vegetables	6.40×10^{-2}	Content, EFH Table 9-27
Animal product consumption rates as consumed (g FW/kg BW/day)	Beef	2.06	EFH Table 13-36, mean intake of homegrown beef for age 20-39.
	Dairy	7.41	EFH Table 13-28, mean intake of home produced dairy for age 20-39.
	Pork	1.21	EFH Table 13-54, mean intake of home produced pork for age 20-39.
Animal product consumption rates dry weight as used in model (g DW/kg BW/day)	Beef	5.85×10^{-1}	Moisture content, EFH Table 11-28
	Dairy	1.37	Avg. moisture content, EFH Table 11-28 and 11-20
	Pork	3.63×10^{-1}	Moisture content, EFH Table 11-28
Contact Fractions	Fraction of day exposed to contaminated air	1	Assumed
	Fraction of consumed products contaminated	1	Assumed

EFH = U.S. Environmental Protection Agency, 1997. Exposure Factors Handbook, Office of Environmental Assessment, Washington, D.C.

Table A-14. High-End Exposure Factors

Exposure	Parameter Value		Source
BWa: Body Weight, adult 20-49 yrs (kg)	71.8		EFH Table 7-11, recommended value
ED: Total exposure duration (yrs)	36.3		EFH Table 15-163, 90th percentile total residence time for farm households based on lognormal distribution using average total residence time and standard deviation
LT: Lifetime (yrs)	75		EFH p. 8-1, recommended value
Daily water Ingestion rate (L/day)	2.30		EFH Table 3-30, 90th percentile value for adult
Water consumption rate (L/kg BW/d)	$3.20x10^{-2}$		Calculated: daily water ingestion rate (L/day)/body weight (kg)
CSA: soil ingestion rate (g/day)	0.1		EFH page 4-21, recommended value for residential and agricultural scenarios for adults
CFAD: fish ingestion rate (g/kg/day)	.319		EFH Tables 10-63 and 10-61, ratio of mean recreational fish intake for age 21-40 in Table 10-61 and mean recreational fish intake in Table 10-63, multiplied by 90th percentile recreational fish intake in Table 10-63
Plant consumption rates as consumed (g FW/kg BW/day)	Grains	5.47	EFH Table 12-1, 90th percentile intake of total grains including mixtures for age 20-39.
	Legumes	1.73	EFH Table 13-64, 90th percentile intake of homegrown protected vegetables for age 20-39.
	Root vegetables	2.11	EFH Table 13-65, 90th percentile intake of homegrown root vegetables for age 20-39.
	Fruits	2.00	EFH Table 13-61, 90th percentile intake of homegrown exposed fruits for age 20-39.
	Leafy vegetables	2.33	EFH Table 13-63, 90th percentile intake of homegrown exposed vegetables for age 20-39.
Plant consumption rates dry weight used in model (g DW/kg BW/day)	Grains	4.90	Calculated: DW = FW * [(100 - % moisture content)/100)] using raw corn-grain-endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	0.33	Calculated: DW = FW * [(100 - % moisture content)/100] using cooked bean 80.75 percent mean moisture content, EFH Table 9-27
	Root vegetables	0.608	Calculated: DW = FW * [(100 - % moisture content)/100] using cooked whole white potatoes 71.2 percent mean moisture content, EFH Table 9-27
	Fruits	0.42	Calculated: DW = FW * [(100 - % moisture content)/100] using fresh apples and bananas (most eaten fruits, per EFH Table 9-25) 79.4 percent mean moisture content, EFH Table 9-27
	Leafy vegetables	0.142	Calculated: DW = FW * [(100 - % moisture content)/100] using lettuce, onion, and tomatoes (most eaten vegetables, per EFH Table 9-25) 93.9 percent mean moisture content, EFH Table 9-27
Animal product consumption rates as consumed (g FW/kg BW/day)	Beef	4.88	EFH Table 13-36, 90th percentile intake of homegrown beef for age 20-39.
	Dairy	15.4	EFH Table 13-28, 90th percentile intake of home produced dairy for age 20-39.
	Pork	2.90	EFH Table 13-54, 90th percentile intake of home produced pork for age 20-39.
Animal product consumption rates dry weight used in model (g DW/kg BW/day)	Beef	1.39	Calculated: DW = FW * [(100 - % moisture content)/100] using 71.6 percent mean moisture content, EFH Table 11-28
	Dairy	2.85	Calculated: DW = FW * [(100 - % moisture content)/100] using 81.5 percent weighted avg. moisture content, EFH Table 11-28 and 11-20
	Pork	0.87	Calculated: DW = FW * [(100 - % moisture content)/100] using 70.0 percent mean moisture content, EFH Table 11-28

Table A-14. High-End Exposure Factors

Exposure	Parameter Value		Source
Contact Fractions	Fraction of day exposed to contaminated air	1	Assumed
	Fraction of consumed products contaminated	1	Assumed

EFH = U.S. Environmental Protection Agency, 1997. Exposure Factors Handbook. EPA/600/P-95/002Fa, Office of Research and Development ,

Table A-15. Site-Specific Site-Department Parameters

Parameters	AK Steel - Middletown, OH	Erie Coke Corporation - Erie, PA	Ak Steel - Ashland, KY	Tonwanda Coke Corp. - Tonawanda, NY
WAL (Watershed info: land area of fallout, km^2)[a]	38.5	7850	38.5	38.5
Water Depth (m)[b]	4.57	9.14	10.7	5.18
WAW: water body surface area (km^2)[c1,c2]	0.7	3930	3.22	5.60
VW: water column volume (m^3)[d]	$3.20\text{x}10^{+6}$	$3.59\text{x}10^{+10}$	$3.44\text{x}10^{+7}$	$2.90\text{x}10^{+7}$
VFX: long term dilution flow (m^3/yr)[e1,e2]	$2.05\text{x}10^{+9}$	$1.79\text{x}10^{+11}$	$7.55\text{x}10^{+10}$	$1.79\text{x}10^{+11}$
U: Average current velocity (m/s)[f1,f2]	0.142	0	0.488	1.37

[A] Based on watershed area modeled in ISCST3: 3.5 km radius for Middletown, Ashland, and Tonawanda, 50 km for Erie

[b] Estimated from personnel at local divisions of the Army Corps of Engineers

[c1] Ashland, Middletown, and Tonawanda facilities: Surface area = length$_{\text{river in watershed area}}$ * width$_{\text{river}}$, where length and width were estimated from maps of the areas

[c2] Erie facility: Surface area = ½ watershed area, estimated from maps of the area

[d] Calculated: surface area * depth

[e1] Ashland, Middletown, and Tonawanda facilities: calculated - annual mean stream flow rates obtained from U.S. Geological Survey (http://waterdata.usgs.gov/nwis/annual) in ft^3/s extrapolated to a yearly total

[e2] Erie facility: Cincinnati default site-dependent value from the Mercury Study: Report to Congress, U.S. Environmental Protection Agency, 1997. Office of Air Quality Planning and Standards, and Office of Research and Development, Research Triangle Park, North Carolina.

[f1] Ashland, Middletown, and Tonawanda facilities: calculated - flow (m/s) / width / depth

[f2] Erie facility: Cincinnati default site-dependent value from the Mercury Study: Report to Congress U.S. Environmental Protection Agency, 1997. Office of Air Quality Planning and Standards, and Office of Research and Development, Research Triangle Park, North Carolina.

Table A-16 Dose-Response Values

Dose-Response Factor	Anthracene	Acenapthene	Benzo(a)pyrene TEQ*	Fluoranthene	Fluorene	Pyrene	Cadmium
Cancer Slope Factor Ingestion (kg-day/mg)			7.3 (IRIS)				15 (CAL)
RfD (mg/kg/day)	0.3	0.06		0.04	0.04	0.03	.003 (food, IRIS) .0005 (water, IRIS)
Source[**]	IRIS	IRIS	IRIS/CAL	IRIS	IRIS	IRIS	IRIS/CAL

* In order to facilitate calculations, seven carcinogenic PAH are combined into a single surrogate pollutant, characterized by benzo(a)pyrene. Concentrations of compounds are adjusted on an "Estimated Order of Potential Potency (EOPP)".

BaP TEQ = ∑ EOPP of 7 carcinogenic PAH * exposure concentration

EOPPs[***]	Benzo(a) pyrene	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Indeno-1,2,3 (cd)pyrene	Dibenz (a,h) anthracene
	1	0.1	0.01	0.1	0.01	0.1	1

[**] CAL: California Environmental Protection Agency, 2002. Technical Support Document for Describing Available Cancer Potency Factors. Office of Environmental Health Hazard Assessment, Sacramento, CA. Online at http://www.oehha.org/air/hotspots/

[**] IRIS: U.S.Environmental Protection Agency. Integrated Risk Information System. Online at http://www.ipa.goviris.html

[***] U.S.Environmental Protection Agency, 1993. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons. Office of Research and Development. EPA/600R-93/089.

Table A-17 Compound-Specific Parameters

Compound-Specific Parameter[a]	Acenaphthene	Anthracene	Benzo(a) anthracene	Benzo(a) pryene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Chrysene	Fluoranthene	Fluorene	Indeno (1,2,3-cd) pyrene	Pyrene	Cadmium
D_w: water diffusion coeff. (cm^2/s)	$7.19x10^{-6}$	$7.74x10^{-6}$	$6.21x10^{-6}$	$5.85x10^{-6}$	$5.49x10^{-6}$	$5.49x10^{-6}$	$6.21x10^{-6}$	$7.18x10^{-6}$	$7.88x10^{-6}$	$5.66x10^{-6}$	$7.14x10^{-6}$	$9.45x10^{-6}$
MW: molecular weight (g/mole)	154	178	228	252	252	252	228	202	166	276	202	112
D (or D_a): Atmospheric diffusion coefficient (cm^2/sec)	$4.21x10^{-2}$	$3.20x10^{-2}$	$2.47x10^{-2}$	$2.18x10^{-2}$	$2.48x10^{-2}$	$2.28x10^{-2}$	$2.47x10^{-2}$	$2.75x10^{-2}$	$3.63x10^{-2}$	$1.90x10^{-2}$	$2.27x10^{-2}$	$8.16x10^{-2}$
H: Henry's Law constant (atm-m^3/mole)	$2.00x10^{-4}$	$1.11x10^{-4}$	$3.62x10^{-6}$	$8.36x10^{-7}$	$6.18x10^{-6}$	$4.15x10^{-7}$	$1.21x10^{-6}$	$9.33x10^{-6}$	$9.41x10^{-8}$	$4.86x10^{-9}$	$1.14x10^{-8}$	0
Kd_s: soil/water partition coefficient (mL/g or	49	235	$2.60x10^{+3}$	$9.69x10^{+3}$	$8.36x10^{+3}$	$8.32x10^{+3}$	$2.97x10^{+3}$	491	77.1	$4.11x10^{+}$	680	75
Kd_w: susp. sed-water partition coefficient (L/kg)	367	$1.76x10^{+3}$	$1.95x10^{+4}$	$7.27x10^{+4}$	$6.27x10^{+4}$	$6.24x10^{+4}$	$2.23x10^{+4}$	$3.68x10^{+3}$	578	$3.08x10^{+}$	$5.10x10^{+}$	75
$Kd_{bs:}$ benthic sed-water partition coefficient	196	940	$1.04x10^{+4}$	$3.87x10^{+4}$	$3.34x10^{+4}$	$3.33x10^{+4}$	$1.19x10^{+4}$	$1.96x10^{+3}$	308	$1.64x10^{+}$	$2.72x10^{+}$	75
Ksg: soil loss degradation constant (1/Yr)	2.48	0.55	0.372	0.477	0.415	0.118	0.253	0.575	4.22	0.347	0.133	0
K_{ow}: octanol/water partition coefficient	$9.22x10^{+3}$	$2.95x10^{+4}$	$4.77x10^{+5}$	$1.35x10^{+6}$	$1.59x10^{+6}$	$1.56x10^{+6}$	$5.48x10^{+5}$	$1.21x10^{+5}$	$1.47x10^{+}$	$8.20x10^{+}$	$1.00x10^{+}$	
Brj: plant-soil bioconcentraion factor (ug/g DW plant per ug/g soil)												
Grains (Br_{ag})	0.198	0.101	$2.02x10^{-2}$	$1.11x10^{-2}$	$1.01x10^{-2}$	$1.01x10^{-2}$	$1.87x10^{-2}$	$4.46x10^{-2}$	0.151	$3.90x10^{-3}$	$4.98x10^{-2}$	$6.20x10^{-2}$
Legumes (Br_{ag})	0.196	0.101	$2.02x10^{-2}$	$1.11x10^{-2}$	$1.01x10^{-2}$	$1.01x10^{-2}$	$1.87x10^{-2}$	$4.46x10^{-2}$	0.151	$3.90x10^{-3}$	$4.98x10^{-2}$	0.125
Root vegetables ($Br_{root\ veg}$)	5.48	2.76	2.11	1.26	1.66	1.66	2.05	3.90	4.96	1.19	2.44	$6.40x10^{-2}$
Fruits (Br_{ag})	0.198	0.101	$2.02x10^{-2}$	$1.11x10^{-2}$	$1.01x10^{-2}$	$1.01x10^{-2}$	$1.87x10^{-2}$	$4.46x10^{-2}$	0.151	$3.90x10^{-3}$	$4.98x10^{-2}$	0.126
Leafy vegetables (Br_{ag})	0.198	0.101	$2.02x10^{-2}$	$1.11x10^{-2}$	$1.01x10^{-2}$	$1.01x10^{-2}$	$1.87x10^{-2}$	$4.46x10^{-2}$	0.151	$3.90x10^{-3}$	$4.98x10^{-2}$	0.125
Forage (Br_{forage})	0.198	0.101	$2.02x10^{-2}$	$1.11x10^{-2}$	$1.01x10^{-2}$	$1.01x10^{-2}$	$1.87x10^{-2}$	$4.46x10^{-2}$	0.151	$3.90x10^{-3}$	$4.98x10^{-2}$	0.364
Silage (Br_{ag})	0.198	0.101	$2.02x10^{-2}$	$1.11x10^{-2}$	$1.01x10^{-2}$	$1.01x10^{-2}$	$1.87x10^{-2}$	$4.46x10^{-2}$	0.151	$3.90x10^{-3}$	$4.98x10^{-2}$	0.125
Bv_1: air-to-plant biotransfer factor (ug/g DW plant per ug/g air)												
Grains	0	0	0	0	0	0	0	0	0	0	0	0
Legumes (Br_{ag})	4.66	29	$1.72x10^{+4}$	$2.25x10^{+5}$	$3.65x10^{+4}$	$5.40x10^{+5}$	$5.97x10^{+4}$	$1.56x10^{+3}$	$1.63x10^{+}$	$2.67x10^{+}$	$1.04x10^{+}$	0
Fruits (Br_{ag})	4.66	29	$1.72x10^{+4}$	$2.25x10^{+5}$	$3.65x10^{+4}$	$5.40x10^{+5}$	$5.97x10^{+4}$	$1.56x10^{+3}$	$1.63x10^{+}$	$2.67x10^{+}$	$1.04x10^{+}$	0
Leafy vegetables (Br_{ag})	4.66	29	$1.72x10^{+4}$	$2.25x10^{+5}$	$3.65x10^{+4}$	$540x10^{+5}$	$5.97x10^{+4}$	$1.56x10^{+3}$	$1.63x10^{+}$	$2.67x10^{+}$	$1.04x10^{+}$	0
Forage (Bv_{forage})	4.66	29	$1.72x10^{+4}$	$2.25x10^{+5}$	$3.65x10^{+4}$	$5.40x10^{+5}$	$5.97x10^{+4}$	$1.56x10^{+3}$	$1.63x10^{+}$	$2.67x10^{+}$	$1.04x10^{+}$	0
Silage (Bv_{ag})	4.66	29	$1.72x10^{+4}$	$2.25x10^{+5}$	$3.65x10^{+4}$	$5.40x10^{+5}$	$5.97x10^{+4}$	$1.56x10^{+3}$	$1.63x10^{+}$	$2.67x10^{+}$	$1.04x10^{+}$	0
Ba_1: biotransfer, jth animal (day/kg FW)[b]												
Beef	$2.00x10^{-4}$	$3.70x10^{-4}$	$1.60x10^{-3}$	$2.80x10^{-3}$	$3.10x10^{-3}$	$3.00x10^{-3}$	$1.70x10^{-3}$	$7.80x10^{-4}$	$2.60x10^{-4}$	$7.30x10^{-3}$	$7.10x10^{-4}$	$1.20x10^{-4}$
Dairy	$1.10x10^{-4}$	$1.80x10^{-4}$	$6.30x10^{-4}$	$9.90x10^{-4}$	$1.10x10^{-3}$	$1.10x10^{-3}$	$6.70x10^{-4}$	$3.40x10^{-4}$	$1.40x10^{-4}$	$2.20x10^{-3}$	$3.20x10^{-4}$	$6.50x10^{-6}$
Pork	$2.42x10^{-4}$	$4.49x10^{-4}$	$1.94x10^{-3}$	$3.39x10^{-3}$	$3.75x10^{-3}$	$3.63x10^{-3}$	$2.06x10^{-3}$	$9.44x10^{-4}$	$3.15x10^{-4}$	$8.84x10^{-3}$	$8.59x10^{-4}$	$1.91x10^{-4}$
Fish Bioaccumulation Factors (BAFs):												
BAF_ W(i): BAF for total water conc. (L/kg)	607											250
BAF_D(i): BAF for diss water conc. (L/kg)		$2.60x10^{+3}$	$5.10x10^{+3}$	$9.95x10^{+3}$	$9.95x10^{+3}$	$9.95x10^{+3}$	$6.03x10^{+3}$	$1.57x10^{+4}$	$1.20x10^{+}$	$1.31x10^{+}$	$1.19x10^{+}$	

[a] Except where otherwise noted, values taken from U.S. Environmental Protection Agency, 1998. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Appendix A. EPA-530-D-98-001A, Office of Solid Waste and Emergency Response, Washington, DC

[b] Developed from Birak, et al., 2001. "Travis and Arms revisited: a second look at a widely used bioconcentration algorithm," Toxicology and Industrial Health, 17, 163-175.

Table A-18. Biotransfer Factors

PAH Biotransfer Factor (BTF) Equations	$\log BTF_{milk}^{a} = m * \log K_{ow} + b$ $\log BTF_{beef}^{a} = m * \log K_{ow} + b$ $BTF_{pork}^{b} = 23/19 * BTF_{beef}$

PAH BTF Equation Variables[a]		**m**	**b**
	Milk	0.44	-5.7
	Beef	0.53	-5.8

HAP	K_{ow}^{b}	**BiotransferFactor:**	**Biotransfer Factor:**	**Biotransfer Factor:**
Anthracene	29500	1.8×10^{-4}	3.7×10^{-4}	4.5×10^{-4}
Benzo(a)anthracene	477000	6.3×10^{-4}	1.6×10^{-3}	2.0×10^{-3}
Chrysene	548000	6.7×10^{-4}	1.7×10^{-3}	2.1×10^{-3}
Benzo(b)fluoranthene	1590000	1.1×10^{-3}	3.1×10^{-3}	3.7×10^{-3}
Benzo(k)fluoranthene	1560000	1.1×10^{-3}	3.0×10^{-3}	3.7×10^{-3}
Benzo(a)pyrene	1350000	9.9×10^{-4}	2.8×10^{-3}	3.4×10^{-3}
Indeno-1,2,3	8220000	2.2×10^{-3}	7.3×10^{-3}	8.9×10^{-3}
Acenaphthene	9220	1.1×10^{-4}	2.0×10^{-4}	2.4×10^{-4}
Fluoranthene	121000	3.4×10^{-4}	7.8×10^{-4}	9.5×10^{-4}
Fluorene	14700	1.4×10^{-4}	2.6×10^{-4}	3.1×10^{-4}
Pyrene	100000	3.2×10^{-4}	7.1×10^{-4}	8.6×10^{-4}
Cadmium	NA	6.5×10^{-6}	1.2×10^{-4}	1.9×10^{-4}

[a] PAH BTF factors calculated with updated information from Birak, et al., 2001, Travis and Arms Revisited: A second look at a widely used bioconcentration algorithm, Toxicology and Industrial Health, 17, 163-175.

[B] U.S.Environmental Protection Agency, 1998. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Appendix C. EPA-530-D-98-001A, Office of Solid Waste and Emergency Response, Washington, DC

Table A-19. Central Tendency Exposure Factors Used in IEUBK Modeling

Age	Central Tendency Exposure Scenario				
	Inhalation Rate (m^3/day)	Water Consumption Rates (L/day)	Soil/Dust Ingestion Rates (µg/g)	Dietary Lead Intake (µg Pb/day)	Time Spent Outdoors (hours/day)
<1	4.5	0.30	0.1	0.067	1
1-2	6.8	0.61	0.1	0.074	2
2-3	6.8	0.61	0.1	0.074	3
3-4	8.3	0.87	0.1	0.058	4
4-5	8.3	0.87	0.1	0.058	4
5-6	8.3	0.87	0.1	0.058	4
6-7	11.75	0.74	0.1	0.085	4

Table A-20. High-End Exposure Factors Used In IEUBK Modeling

Age	High-End Exposure Scenario				
	Inhalation Rate (m^3/day)	Water Consumption Rates (L/day)	Soil/Dust Ingestion Rates (µg/g)	Dietary Lead Intake (µg Pb/day)	Time Spent Outdoors (hours/day)
<1	5.5	0.65	0.4	0.190	1
1-2	8.33	1.5	0.4	0.138	2
2-3	8.33	1.5	0.4	0.138	3
3-4	10.17	1.5	0.4	0.114	4
4-5	10.17	1.5	0.4	0.114	4
5-6	10.17	1.5	0.4	0.114	4
6-7	14.4	1.3	0.4	0.203	4

Table A-21. Other IEUBK Inputs Used for All Ages and Exposure Scenarios

Parameter	Units	Value
Lead concentration in outdoor air	µg/m^3	0.00054
Lead concentration in drinking water	µg/L	0.000021
Lead concentration in soil	µg/g	0.169
Lead concentration in dust	µg/g	0.169
Ratio of indoor to outdoor air lead concentration	NA	1:1
Mother's blood lead level at time of birth	µg/dL	2.5
Additional lead intake	µg/day	0.0
Lung absorption	percentage lead absorbed	32
Total lead absorption from food and water (at low intake)	percentage lead absorbed	50
Total lead absorption from soil and dust (at low intake)	percentage lead absorbed	30
Total lead absorbed passively (at high intake) for all ingestion pathways	percentage lead absorbed	20

Table A-22 Lead Concentration Inputs for IEUBK model for AK Steel - Ashland Facility

Parameter		Value
Air Concentration (ug/m3)		5.4×10^{-4}
Total Plant Concentration (ug/g)	Grains	7.1×10^{-5}
	Legumes	4.8×10^{-4}
	Root vegetables (includes potatoes)	1.4×10^{-4}
	Fruits	2.4×10^{-3}
	Leafy vegetables (exposed vegetables, incl. fruiting vegetables)	6.8×10^{-3}
Animal Product Concentration (ug/g)	Beef	6.1×10^{-5}
	Dairy	6.1×10^{-5}
	Pork	2.2×10^{-5}
Terrestrial Soil Concentrations (ug/g)		1.69×10^{-1}
Water Concentrations (mg/L)		2.1×10^{-8}
Fish Concentrations (mg/g)		1.7×10^{-10}

Table A-23. High-End Exposure Dietary Intake Rate Input to IEUBK

Total Concentration (µg Pb/day)				
Food	**Age <1**	**Age 1 to 2**	**Age 3 to 5**	**Age 6 to 11**
Grains	9.70×10^{-3}	1.48×10^{-2}	1.68×10^{-2}	2.01×10^{-2}
Legumes	1.17×10^{-2}	4.41×10^{-3}	4.06×10^{-3}	6.09×10^{-3}
Root	1.82×10^{-3}	3.60×10^{-3}	3.01×10^{-3}	4.76×10^{-3}
Fruits	1.26×10^{-1}	9.59×10^{-2}	4.77×10^{-2}	1.08×10^{-1}
Leafy	1.48×10^{-2}	5.85×10^{-3}	2.52×10^{-2}	4.11×10^{-2}
Beef	1.19×10^{-3}	1.76×10^{-3}	2.85×10^{-3}	6.08×10^{-3}
Dairy	2.45×10^{-2}	1.11×10^{-2}	1.36×10^{-2}	1.54×10^{-2}
Pork	1.95×10^{-4}	5.83×10^{-4}	7.47×10^{-4}	1.05×10^{-3}
Fish	0e+00	1.77×10^{-6}	2.52×10^{-6}	3.31×10^{-6}
Total	**0.19**	**0.14**	**0.11**	**0.20**

Calculation: food concentration * body weight *consumption rate (see the following Tables for the input information.

Table A-24. Lead Concentration of Foods

Food	Lead Concentration (ug/g)
Grains	7.10×10^{-5}
Legumes	4.80×10^{-4}
Root Vegetables	1.40×10^{-4}
Fruits	2.40×10^{-3}
Leafy Vegetables	6.80×10^{-3}
Beef	6.10×10^{-5}
Dairy	6.10×10^{-5}
Pork	2.20×10^{-5}
Fish	1.70×10^{-7}

These values are outputs from IEM-2M

Table A-25. Body Weights versus Age

Age	Body Weight (kg)
<1	9.1
1 to 2	12.3
3 to 5	17.5
6 to 11	30.8

Table A-26. Food Consumption Rate : grams Drinking Water/ kg Body Weight/ Day

Food	Age <1	Age 1 to 2	Age 3 to 5	Age 6 to
Grains	15.013	16.958	13.561	9.196
Legumes	2.684	0.747	0.483	0.412
Root Vegetables	1.432	2.088	1.227	1.103
Fruits	5.770	3.250	1.136	1.466
Leafy Vegetables	0.239	0.070	0.212	0.196
Beef	2.139	2.347	2.668	3.238
Dairy	44.171	14.774	12.777	8.201
Pork	0.976	2.156	1.940	1.552
Fish	0	0.847	0.847	0.633

Calculation: grams drinking water/ kg body weight / day)
Source: Exposure Factors Handbook)

Table A-27. Central Tendency Exposure Dietary Intake Rate Input to IEUBK

Food	Total Concentration (ug Pb/day)			
	Age <1	Age 1 to 2	Age 3 to 5	Age 6 to 11
Grains	0.004	0.008	0.011	0.013
Legumes	0.003	0.003	0.002	0.003
Root Vegs	0.001	0.001	0.001	0.002
Fruits	0.043	0.036	0.023	0.039
Leafy Vegs	0.005	0.018	0.013	0.018
Beef	0.000	0.001	0.001	0.002
Dairy	0.011	0.006	0.007	0.008
Pork	0.000	8.24×10^{-5}	8.24×10^{-5}	8.24×10^{-5}
Fish	0.000	8.24×10^{-5}	8.24×10^{-5}	8.24×10^{-5}
Total	**0.067**	**0.074**	**0.058**	**0.085**

Calculation: food concentration * body weight *consumption rate (see the following Tables for the input information.

Table A-28. Food Consumption Rate : grams Drinking Water/ kg Body Weight/ Day

Food	Age <1	Age 1 to 2	Age 3 to 5	Age 6 to 11
Grains	6.318	9.471	8.508	5.756
Legumes	0.670	0.474	0.250	0.212
Root Vegs	0.498	0.726	0.369	0.380
Fruits	1.970	1.220	0.546	0.529
Leafy Vegs	0.075	0.213	0.106	0.085
Beef	0.794	1.231	1.174	1.071
Dairy	20.272	8.486	6.834	4.309
Pork	0.411	0.696	0.669	0.498
Fish	0	0.369	0.369	0.276

Source: Exposure Factors Handbook

Table A-29. High-End Exposure Parameters

Parameter	Age Group	Value	Source
Body Weights (kg)	Infant, < 1yr old	9.1	EFH Table 7-3. Mean value for 6-11 month olds, boys & girls
	Child, 1-2 yr old	12.3	EFH Table 7-3. Mean value for 1-2 year olds, boys & girls
	Child, 3-5 yr old	17.5	EFH Table 7-3. Mean value for 3-5 year olds, boys & girls
	Child, 6-11 yr old	30.8	EFH Table 7-3. Mean value for 6-11 year olds, boys & girls
Inhalation Rates (m^3/day)	Infant, < 1yr old	5.51	Calculated: Age <1 mean inhalation rate (EFH Table 5-23) divided by ratio of all children inhalation rate mean (CAL Table 3-20) to 90th percentile all children inhaltion rate (CAL Table 3-20)
	Child, 1-2 yr old	8.33	Calculated: Age 1-2 mean inhalation rate (EFH Table 5-23) divided by ratio of all children inhalation rate mean (CAL Table 3-20) to 90th percentile all children inhaltion rate (CAL Table 3-20)
	Child, 3-5 yr old	10.17	Calculated: Age 3-5 mean inhalation rate (EFH Table 5-23) divided by ratio of all children inhalation rate mean (CAL Table 3-20) to 90th percentile all children inhaltion rate (CAL Table 3-20)
	Child, 6-11 yr old	14.40	Calculated: Age 6-11 average of mean inhalation rates (EFH Table 5-23) divided by ratio of all children inhalation rate mean (CAL Table 3-20) to 90th percentile all children inhaltion rate (CAL Table 3-20)
Water Ingestion Rates (l/day)	Infant, < 1yr old	0.65	EFH Table 3-30. 90th percentile value for age <1
	Child, 1-2 yr old	1.50	EFH Table 3-30. 90th percentile value for age <3
	Child, 3-5 yr old	1.50	EFH Table 3-30. 90th percentile value for age 3-5
	Child, 6-11 yr old	1.30	EFH Table 3-30. 90th percentile value for age 1-10
Water Consumption Rates L/kg BW/d	Infant, < 1yr old	0.07	Calculated: Consumption rate = Ingestion rate/body weight
	Child, 1-2 yr old	0.12	Calculated: Consumption rate = Ingestion rate/body weight
	Child, 3-5 yr old	0.09	Calculated: Consumption rate = Ingestion rate/body weight
	Child, 6-11 yr old	0.04	Calculated: Consumption rate = Ingestion rate/body weight
Soil Ingestion Rate (g/day)	Child	0.40	EFH, p 4-20, recommended upper percentile value for children
Plant Consumption Rates As Consumed (g FW/kg BW/day)	**Infant, < 1yr old**		
	Grains	16.75	EFH Table 12-1. 90th percentile value for age <1
	Legumes	13.95	Calculated: Age <1 intake 90th percentile (EFH Table 9-10) divided by ratio of all ages intake mean (EFH Table 9-10) to all ages home produced mean (EFH Table 13-64)
	Root vegetables	4.97	Calculated: Age <1 intake 90th percentile (EFH Table 9-11) divided by ratio of all ages intake mean (EFH Table 9-11) to all ages home produced mean (EFH Table 13-65)
	Fruits	28.01	Calculated: Age <1 intake 90th percentile (EFH Table 9-7) divided by ratio of all ages intake mean (EFH Table 9-7) to all ages home produced mean (EFH Table 13-61)
	Leafy vegetables	3.91	Calculated: Age <1 intake 90th percentile (EFH Table 9-9) divided by ratio of all ages intake mean (EFH Table 9-9) to all ages home produced mean (EFH Table 13-63)
	Child, 1-2 yr old		
	Grains	18.92	EFH Table 12-1. 90th percentile value for age 1-2
	Legumes	3.88	EFH Table 13-64. 90th percentile value for age 1-2
	Root vegetables	7.25	EFH Table 13-65. 90th percentile value for age 1-2
	Fruits	15.77	Calculated: Age 1-2 intake 90th percentile (EFH Table 9-7) divided by ratio of all ages intake mean (EFH Table 9-7) to all ages home produced mean (EFH Table 13-61)
	Leafy vegetables	1.07	EFH Table 13-63. 90th percentile value for age 1-2
	Child, 3-5 yr old		
	Grains	15.13	EFH Table 12-1. 90th percentile value for age 3-5
	Legumes	2.51	EFH Table 13-64. 90th percentile value for age 3-5
	Root vegetables	4.26	EFH Table 13-65. 90th percentile value for age 3-5
	Fruits	5.41	EFH Table13-61. 90th percentile value for age 3-5
	Leafy vegetables	3.47	EFH Table 13-63. 90th percentile value for age 3-5
	Child, 6-11 yr old		
	Grains	10.26	EFH Table 12-1. 90th percentile value for age 6-11
	Legumes	2.14	EFH Table 13-64. 90th percentile value for age 6-11
	Root vegetables	3.83	EFH Table 13-65. 90th percentile value for age 6-11
	Fruits	6.98	EFH Table 13-61. 90th percentile value for age 6-11
	Leafy vegetables	3.22	EFH Table 13-63. 90th percentile value for age 6-11

Table A-29. High-End Exposure Parameters

Parameter	Age Group	Value	Source
Plant Consumption Rates Dry Weight As Used In Model (g DW/kg BW/day)	**Infant, < 1yr old**		
	Grains	15.01	Calculated: DW = FW*[(100-%moisture content)/100] using raw corn-grain-endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	2.68	Calculated: DW = FW*[(100-%moisture content)/100] using cooked bean 80.75 percent mean moisture content, EFH Table 9-27
	Root vegetables	1.43	Calculated: DW = FW*[(100-%moisture content)/100] using cooked whole white potatoes 71.2 percent mean moisture content, EFH Table 9-27
	Fruits	5.77	Calculated: DW = FW*[(100-%moisture content)/100] using fresh apples and bananas (most eaten fruits, per EFH Table 9-25) 79.4 percent mean moisture content, EFH Table 9-27
	Leafy vegetables	0.24	Calculated: DW = FW*[(100-%moisture content)/100] using lettuce, onion, and tomatoes (most eaten vegetables, per EFH Table 9-25) 93.9 percent mean moisture content, EFH Table 9-27
	Child, 1-2 yr old		
	Grains	16.96	Calculated: DW = FW*[(100-%moisture content)/100] using raw corn-grain-endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	0.75	Calculated: DW = FW*[(100-%moisture content)/100] using cooked bean 80.75 percent mean moisture content, EFH Table 9-27
	Root vegetables	2.09	Calculated: DW = FW*[(100-%moisture content)/100] using cooked whole white potatoes 71.2 percent mean moisture content, EFH Table 9-27
	Fruits	3.25	Calculated: DW = FW*[(100-%moisture content)/100] using fresh apples and bananas (most eaten fruits, per EFH Table 9-25) 79.4 percent mean moisture content, EFH Table 9-27
	Leafy vegetables	0.07	Calculated: DW = FW*[(100-%moisture content)/100] using lettuce, onion, and tomatoes (most eaten vegetables, per EFH Table 9-25) 93.9 percent mean moisture content, EFH Table 9-27
	Child, 3-5 yr old		
	Grains	13.56	Calculated: DW = FW*[(100-%moisture content)/100] using raw corn-grain-endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	0.48	Calculated: DW = FW*[(100-%moisture content)/100] using cooked bean 80.75 percent mean moisture content, EFH Table 9-27
	Root vegetables	1.23	Calculated: DW = FW*[(100-%moisture content)/100] using cooked whole white potatoes 71.2 percent mean moisture content, EFH Table 9-27
	Fruits	1.14	Calculated: DW = FW*[(100-%moisture content)/100] using fresh apples and bananas (most eaten fruits, per EFH Table 9-25) 79.4 percent mean moisture content, EFH Table 9-27
	Leafy vegetables	0.21	Calculated: DW = FW*[(100-%moisture content)/100] using lettuce, onion, and tomatoes (most eaten vegetables, per EFH Table 9-25) 93.9 percent mean moisture content, EFH Table 9-27
	Child, 6-11 yr old		
	Grains	9.20	Calculated: DW = FW*[(100-%moisture content)/100] using raw corn-grain-endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	0.41	Calculated: DW = FW*[(100-%moisture content)/100] using cooked bean 80.75 percent mean moisture content, EFH Table 9-27
	Root vegetables	1.10	Calculated: DW = FW*[(100-%moisture content)/100] using cooked whole white potatoes 71.2 percent mean moisture content, EFH Table 9-27
	Fruits	1.47	Calculated: DW = FW*[(100-%moisture content)/100] using fresh apples and bananas (most eaten fruits, per EFH Table 9-25) 79.4 percent mean moisture content, EFH Table 9-27
	Leafy vegetables	0.20	Calculated: DW = FW*[(100-%moisture content)/100] using lettuce, onion, and tomatoes (most eaten vegetables, per EFH Table 9-25 93.9 percent mean moisture content, EFH Table 9-27
Animal Product Consumption Rates As Consumed (g FW/kg BW/day)	**Infant, < 1yr old**		
	Beef	7.53	Calculated: Age <1 intake 90th percentile (EFH Table 11-3) divided by ratio of all ages intake mean (EFH Table 11-3) to all ages home produced mean (EFH Table 13-36)
	Dairy	238.76	Calculated: Age <1 intake 90th percentile (EFH Table 11-2) divided by ratio of all ages intake mean (EFH Table 11-2) to all ages home produced mean (EFH Table 13-28)
	Pork	3.25	Calculated: Age <1 intake 90th percentile (EFH Table 11-4) divided by ratio of all ages intake mean (EFH Table 11-4) to all ages home produced mean (EFH Table 13-54)
	Child, 1-2 yr old		
	Beef	8.26	Calculated: Age 1-2 intake 90th percentile (EFH Table 11-3) divided by ratio of all ages intake mean (EFH Table 11-3) to all ages home produced mean (EFH Table 13-36)
	Dairy	79.86	Calculated: Age 1-2 intake 90th percentile (EFH Table 11-2) divided by ratio of all ages intake mean (EFH Table 11-2) to all ages home produced mean (EFH Table 13-28)
	Pork	7.19	Calculated: Age 1-2 intake 90th percentile (EFH Table 11-4) divided by ratio of all ages intake mean (EFH Table 11-4) to all ages home produced mean (EFH Table 13-54)
	Child, 3-5 yr old		
	Beef	9.39	Calculated: Age 3-5 intake 90th percentile (EFH Table 11-3) divided by ratio of all ages intake mean (EFH Table 11-3) to all ages home produced mean (EFH Table 13-36)

Table A-29. High-End Exposure Parameters

Parameter	Age Group	Value	Source
	Dairy	69.07	Calculated: Age 3-5 intake 90th percentile (EFH Table 11-2) divided by ratio of all ages intake mean (EFH Table 11-2) to all ages home produced mean (EFH Table 13-28)
	Pork	6.47	Calculated: Age 3-5 intake 90th percentile (EFH Table 11-4) divided by ratio of all ages intake mean (EFH Table 11-4) to all ages home produced mean (EFH Table 13-54)
	Child, 6-11 yr old		
	Beef	11.40	EFH Table 13-36. 90th percentile value for age 6-11
	Dairy	44.33	Calculated: Age 6-11 intake 90th percentile (EFH Table 11-2) divided by ratio of all ages intake mean (EFH Table 11-2) to all ages home produced mean (EFH Table 13-28)
	Pork	5.17	Calculated: Age 6-11 intake 90th percentile (EFH Table 11-4) divided by ratio of all ages intake mean (EFH Table 11-4) to all ages home produced mean (EFH Table 13-54)
Animal Product Consumption Rates Dry Weight As Used In Model (g DW/kg BW/day)	**Infant, < 1yr old**		
	Beef	2.14	Calculated: DW = FW*[(100-%moisture content)/100] using 71.6 percent mean moisture content, EFH Table 11-28
	Dairy	44.17	Calculated: DW = FW*[(100-%moisture content)/100] using 81.5 percent weighted avg. moisture content, EFH Table 11-28 and 11-20
	Pork	0.98	Calculated: DW = FW*[(100-%moisture content)/100] using 70.0 percent mean moisture content, EFH Table 11-28
	Child, 1-2 yr old		
	Beef	2.35	Calculated: DW = FW*[(100-%moisture content)/100] using 71.6 percent mean moisture content, EFH Table 11-28
	Dairy	14.77	Calculated: DW = FW*[(100-%moisture content)/100] using 81.5 percent weighted avg. moisture content, EFH Table 11-28 and 11-20
	Pork	2.16	Calculated: DW = FW*[(100-%moisture content)/100] using 70.0 percent mean moisture content, EFH Table 11-28
	Child, 3-5 yr old		
	Beef	2.67	Calculated: DW = FW*[(100-%moisture content)/100] using 71.6 percent mean moisture content, EFH Table 11-28
	Dairy	12.78	Calculated: DW = FW*[(100-%moisture content)/100] using 81.5 percent weighted avg. moisture content, EFH Table 11-28 and 11-20
	Pork	1.94	Calculated: DW = FW*[(100-%moisture content)/100] using 70.0 percent mean moisture content, EFH Table 11-28
	Child, 6-11 yr old		
	Beef	3.24	Calculated: DW = FW*[(100-%moisture content)/100] using 71.6 percent mean moisture content, EFH Table 11-28
	Dairy	8.20	Calculated: DW = FW*[(100-%moisture content)/100] using 81.5 percent weighted avg. moisture content, EFH Table 11-28 and 11-20
	Pork	1.55	Calculated: DW = FW*[(100-%moisture content)/100] using 70.0 percent mean moisture content, EFH Table 11-28
Fish Ingestion Rates (g/kg/day)	Child, 1-2 yr old	0.85	EFH Tables 10-63 and 10-61, ratio of mean recreational fish intake for age 1-5 in table 10-61 and mean recreational fish intake in table 10-63, multiplied by 90th percentile recreational fish intake in table 10-63
	Child, 3-5 yr old	0.85	EFH Tables 10-63 and 10-61, ratio of mean recreational fish intake for age 1-5 in table 10-61 and mean recreational fish intake in table 10-63, multiplied by 90th percentile recreational fish intake in table 10-63
	Child, 6-11 yr old	0.63	EFH Tables 10-63 and 10-61, ratio of mean recreational fish intake for age 6-10 in table 10-61 and mean recreational fish intake in table 10-63, multiplied by 90th percentile recreational fish intake in table 10-63

EFH = U.S. Environmental Protection Agency, 1997. *Exposure Factors Handbook*. EPA/600/P-95/002Fa, Office of Research and Development and National Center for Environmental Assessment, Washington, D.C.

CAL = California Environmental Protection Agency, 2000. *Air Toxics Hot Spots Program Risk Assessment Guidelines Part IV. Technical Support Document. Exposure Assessment and Stochastic Analysis.* Oakland, California.

Table A-30. Central Tendency Exposure Parameters

Parameter	Age Group	Value	Source
Body Weights (kg)	Infant, < 1yr old	9.1	EFH Table 7-3. Mean value for 6-11 month olds, boys & girls
	Child, 1-2 yr old	12.3	EFH Table 7-3. Mean value for 1-2 year olds, boys & girls
	Child, 3-5 yr old	17.5	EFH Table 7-3. Mean value for 3-5 year olds, boys & girls
	Child, 6-11 yr old	30.8	EFH Table 7-3. Mean value for 6-11 year olds, boys & girls
Inhalation Rates (m^3/day)	Infant, < 1yr old	4.5	EFH Table 5-23. Mean value for age <1
	Child, 1-2 yr old	6.8	EFH Table 5-23. Mean value for age 1-2
	Child, 3-5 yr old	8.3	EFH Table 5-23. Mean value for age 3-5
	Child, 6-11 yr old	11.75	EFH Table 5-23. Average of mean values for ages 6-8 and 9-11 males and females
Water Ingestion Rates (l/day)	Infant, < 1yr old	0.30	EFH Table 3-30. Mean value for age <1
	Child, 1-2 yr old	0.61	EFH Table 3-30. Mean value for age <3
	Child, 3-5 yr old	0.87	EFH Table 3-30. Mean value for age 3-5
	Child, 6-11 yr old	0.74	EFH Table 3-30. Mean value for age 1-10
Water Consumption Rates L/kg BW/d	Infant, < 1yr old	0.03	Calculated: Consumption rate = Ingestion rate/body weight
	Child, 1-2 yr old	0.05	Calculated: Consumption rate = Ingestion rate/body weight
	Child, 3-5 yr old	0.05	Calculated: Consumption rate = Ingestion rate/body weight
	Child, 6-11 yr old	0.02	Calculated: Consumption rate = Ingestion rate/body weight
Soil Ingestion Rate (g/day)	Child	0.10	EFH, p 4-25, recommended value for children (mean, non-pica)
Plant Consumption Rates As Consumed (g FW/kg BW/day)	**Infant, < 1yr old**		
	Grains	7.05	EFH Table 12-1. Mean value for age <1
	Legumes	3.48	Calculated: Age <1 intake mean (EFH Table 9-10) divided by ratio of all ages intake mear (EFH Table 9-10) to all ages home produced mean (EFH Table 13-64)
	Root vegetables	1.73	Calculated: Age <1 intake mean (EFH Table 9-11) divided by ratio of all ages intake mear (EFH Table 9-11) to all ages home produced mean (EFH Table 13-65)
	Fruits	9.58	Calculated: Age <1 intake mean (EFH Table 9-7) divided by ratio of all ages intake mean (EFH Table 9-7) to all ages home produced mean (EFH Table 13-61)
	Leafy vegetables	1.23	Calculated: Age <1 intake mean (EFH Table 9-9) divided by ratio of all ages intake mean (EFH Table 9-9) to all ages home produced mean (EFH Table 13-63)
	Child, 1-2 yr old		
	Grains	10.57	EFH Table 12-1. Mean value for age 1-2
	Legumes	2.46	EFH Table 13-64. Mean value for age 1-2
	Root vegetables	2.52	EFH Table 13-65. Mean value for age 1-2
	Fruits	5.90	Calculated: Age 1-2 intake mean (EFH Table 9-7) divided by ratio of all ages intake mean (EFH Table 9-7) to all ages home produced mean (EFH Table 13-61)
	Leafy vegetables	3.48	EFH Table 13-63. Mean value for age 1-2
	Child, 3-5 yr old		
	Grains	9.49	EFH Table 12-1. Mean value for age 3-5
	Legumes	1.30	EFH Table 13-64. Mean value for age 3-5
	Root vegetables	1.28	EFH Table 13-65. Mean value for age 3-5
	Fruits	2.60	EFH Table13-61. Mean value for age 3-5
	Leafy vegetables	1.74	EFH Table 13-63. Mean value for age 3-5
	Child, 6-11 yr old		
	Grains	6.42	EFH Table 12-1. Mean value for age 6-11
	Legumes	1.10	EFH Table 13-64. Mean value for age 6-11
	Root vegetables	1.32	EFH Table 13-65. Mean value for age 6-11
	Fruits	2.52	EFH Table 13-61. Mean value for age 6-11
	Leafy vegetables	1.39	EFH Table 13-63. Mean value for age 6-11
Plant Consumption Rates Dry Weight As Used In Model (g DW/kg BW/day)	**Infant, < 1yr old**		
	Grains	6.32	Calculated: DW = FW*[(100-%moisture content)/100] using raw corn-grain-endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	0.67	Calculated: DW = FW*[(100-%moisture content)/100] using cooked bean 80.75 percent mean moisture content, EFH Table 9-27
	Root vegetables	0.50	Calculated: DW = FW*[(100-%moisture content)/100] using cooked whole white potatoes

Table A-30. Central Tendency Exposure Parameters

Parameter	Age Group	Value	Source
			71.2 percent mean moisture content, EFH Table 9-27
	Fruits	1.97	Calculated: DW = FW*[(100-%moisture content)/100] using fresh apples and bananas (most eaten fruits, per EFH Table 9-25) 79.4 percent mean moisture content, EFH Table 9-27
	Leafy vegetables	0.08	Calculated: DW = FW*[(100-%moisture content)/100] using lettuce, onion, and tomatoes (most eaten vegetables, per EFH Table 9-25) 93.9 percent mean moisture content, EFH Table 9-27
	Child, 1-2 yr old		
	Grains	9.47	Calculated: DW = FW*[(100-%moisture content)/100] using raw corn-grain-endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	0.47	Calculated: DW = FW*[(100-%moisture content)/100] using cooked bean 80.75 percent mean moisture content, EFH Table 9-27
	Root vegetables	0.73	Calculated: DW = FW*[(100-%moisture content)/100] using cooked whole white potatoes 71.2 percent mean moisture content, EFH Table 9-27
	Fruits	1.22	Calculated: DW = FW*[(100-%moisture content)/100] using fresh apples and bananas (most eaten fruits, per EFH Table 9-25) 79.4 percent mean moisture content, EFH Table 9-27
	Leafy vegetables	0.21	Calculated: DW = FW*[(100-%moisture content)/100] using lettuce, onion, and tomatoes (most eaten vegetables, per EFH Table 9-25) 93.9 percent mean moisture content, EFH Table 9-27
	Child, 3-5 yr old		
	Grains	8.51	Calculated: DW = FW*[(100-%moisture content)/100] using raw corn-grain-endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	0.25	Calculated: DW = FW*[(100-%moisture content)/100] using cooked bean 80.75 percent mean moisture content, EFH Table 9-27
	Root vegetables	0.37	Calculated: DW = FW*[(100-%moisture content)/100] using cooked whole white potatoes 71.2 percent mean moisture content, EFH Table 9-27
	Fruits	0.55	Calculated: DW = FW*[(100-%moisture content)/100] using fresh apples and bananas (most eaten fruits, per EFH Table 9-25) 79.4 percent mean moisture content, EFH Table 9-27
	Leafy vegetables	0.11	Calculated: DW = FW*[(100-%moisture content)/100] using lettuce, onion, and tomatoes (most eaten vegetables, per EFH Table 9-25) 93.9 percent mean moisture content, EFH Table 9-27
	Child, 6-11 yr old		
	Grains	5.76	Calculated: DW = FW*[(100-%moisture content)/100] using raw corn-grain-endosperm 10.37 percent moisture content, EFH Table 12-21
	Legumes	0.21	Calculated: DW = FW*[(100-%moisture content)/100] using cooked bean 80.75 percent mean moisture content, EFH Table 9-27
	Root vegetables	0.38	Calculated: DW = FW*[(100-%moisture content)/100] using cooked whole white potatoes 71.2 percent mean moisture content, EFH Table 9-27
	Fruits	0.53	Calculated: DW = FW*[(100-%moisture content)/100] using fresh apples and bananas (most eaten fruits, per EFH Table 9-25) 79.4 percent mean moisture content, EFH Table 9-27
	Leafy vegetables	0.08	Calculated: DW = FW*[(100-%moisture content)/100] using lettuce, onion, and tomatoes (most eaten vegetables, per EFH Table 9-25) 93.9 percent mean moisture content, EFH Table 9-27

Table A-30. Central Tendency Exposure Parameters

Parameter	Age Group	Value	Source
Animal Product Consumption Rates As Consumed (g FW/kg BW/day)	**Infant, < 1yr old**		
	Beef	2.79	Calculated: Age <1 intake mean (EFH Table 11-3) divided by ratio of all ages intake mean (EFH Table 11-3) to all ages home produced mean (EFH Table 13-36)
	Dairy	109.58	Calculated: Age <1 intake mean (EFH Table 11-2) divided by ratio of all ages intake mean (EFH Table 11-2) to all ages home produced mean (EFH Table 13-28)
	Pork	1.37	Calculated: Age <1 intake mean (EFH Table 11-4) divided by ratio of all ages intake mean (EFH Table 11-4) to all ages home produced mean (EFH Table 13-54)
	Child, 1-2 yr old		
	Beef	4.34	Calculated: Age 1-2 intake mean (EFH Table 11-3) divided by ratio of all ages intake mean (EFH Table 11-3) to all ages home produced mean (EFH Table 13-36)
	Dairy	45.87	Calculated: Age 1-2 intake mean (EFH Table 11-2) divided by ratio of all ages intake mean (EFH Table 11-2) to all ages home produced mean (EFH Table 13-28)
	Pork	2.32	Calculated: Age 1-2 intake mean (EFH Table 11-4) divided by ratio of all ages intake mean (EFH Table 11-4) to all ages home produced mean (EFH Table 13-54)
	Child, 3-5 yr old		
	Beef	4.13	Calculated: Age 3-5 intake mean (EFH Table 11-3) divided by ratio of all ages intake mean (EFH Table 11-3) to all ages home produced mean (EFH Table 13-36)
	Dairy	36.94	Calculated: Age 3-5 intake mean (EFH Table 11-2) divided by ratio of all ages intake mean (EFH Table 11-2) to all ages home produced mean (EFH Table 13-28)
	Pork	2.23	Calculated: Age 3-5 intake mean (EFH Table 11-4) divided by ratio of all ages intake mean (EFH Table 11-4) to all ages home produced mean (EFH Table 13-54)
	Child, 6-11 yr old		
	Beef	3.77	EFH Table 13-36. Mean value for age 6-11
	Dairy	23.29	Calculated: Age 6-11 intake mean (EFH Table 11-2) divided by ratio of all ages intake mean (EFH Table 11-2) to all ages home produced mean (EFH Table 13-28)
	Pork	1.66	Calculated: Age 6-11 intake mean (EFH Table 11-4) divided by ratio of all ages intake mean (EFH Table 11-4) to all ages home produced mean (EFH Table 13-54)
Animal Product Consumption Rates Dry Weight As Used In Model (g DW/kg BW/day)	**Infant, < 1yr old**		
	Beef	0.79	Calculated: DW = FW*[(100-%moisture content)/100] using 71.6 percent mean moisture content, EFH Table 11-28
	Dairy	20.27	Calculated: DW = FW*[(100-%moisture content)/100] using 81.5 percent weighted avg. moisture content, EFH Table 11-28 and 11-20
	Pork	0.41	Calculated: DW = FW*[(100-%moisture content)/100] using 70.0 percent mean moisture content, EFH Table 11-28
	Child, 1-2 yr old		
	Beef	1.23	Calculated: DW = FW*[(100-%moisture content)/100] using 71.6 percent mean moisture content, EFH Table 11-28
	Dairy	8.49	Calculated: DW = FW*[(100-%moisture content)/100] using 81.5 percent weighted avg. moisture content, EFH Table 11-28 and 11-20
	Pork	0.70	Calculated: DW = FW*[(100-%moisture content)/100] using 70.0 percent mean moisture content, EFH Table 11-28
	Child, 3-5 yr old		
	Beef	1.17	Calculated: DW = FW*[(100-%moisture content)/100] using 71.6 percent mean moisture content, EFH Table 11-28
	Dairy	6.83	Calculated: DW = FW*[(100-%moisture content)/100] using 81.5 percent weighted avg. moisture content, EFH Table 11-28 and 11-20
	Pork	0.67	Calculated: DW = FW*[(100-%moisture content)/100] using 70.0 percent mean moisture content, EFH Table 11-28
	Child, 6-11 yr old		
	Beef	1.07	Calculated: DW = FW*[(100-%moisture content)/100] using 71.6 percent mean moisture content, EFH Table 11-28
	Dairy	4.31	Calculated: DW = FW*[(100-%moisture content)/100] using 81.5 percent weighted avg. moisture content, EFH Table 11-28 and 11-20
	Pork	0.50	Calculated: DW = FW*[(100-%moisture content)/100] using 70.0 percent mean moisture content, EFH Table 11-28
Fish Ingestion Rates (g/kg/day)	Child, 1-2 yr old	0.37	EFH Table 10-61, Mean value for ages 0-5
	Child, 3-5 yr old	0.37	EFH Table 10-61, Mean value for ages 0-5

Table A-30. Central Tendency Exposure Parameters

Parameter	Age Group	Value	Source
	Child, 6-11 yr old	0.28	EFH Table 10-61, Mean value for ages 6-10

EFH = U.S. Environmental Protection Agency, 1997. *Exposure Factors Handbook*. EPA/600/P-95/002Fa, Office of Research and Development and National Center for Environmental Assessment, Washington, D.C.

Table A-31. Multipathway Results for AK-Ashland

Substance	Soil	Produce	Animal Product	Water	Fish	Total Ingestion
Ingestion Cancer Risk- Central Tendency						
Acenapthene						
Benzo(a)pyrene TEQ	$6x10^{-9}$	$4x10^{-6}$	$3x10^{-6}$	$9x10^{-11}$	$6x10^{-9}$	$7x10^{-6}$
Anthracene						
Fluoranthene						
Fluorene						
Pyrene						
Cadmium	$3x10^{-9}$	$2x10^{-7}$	$2x10^{-9}$	$7x10^{-11}$	$1x10^{-10}$	$2x10^{-7}$
Total Pathway Risk	**$9x10^{-9}$**	**$4x10^{-6}$**	**$3x10^{-6}$**	**$2x10^{-10}$**	**$6x10^{-9}$**	**$7x10^{-6}$**
Hazard Quotient-Central Tendency						
Acenapthene	$7x10^{-11}$	$7x10^{-7}$	$2x10^{-8}$	$1x10^{-10}$	$2x10^{-9}$	$7x10^{-7}$
Benzo(a)pyrene TEQ						
Anthracene	$1x10^{-12}$	$9x10^{-8}$	$2x10^{-9}$	$2x10^{-11}$	$9x10^{-11}$	$9x10^{-8}$
Fluoranthene	$2x10^{-8}$	$3x10^{-5}$	$7x10^{-7}$	$3x10^{-9}$	$4x10^{-7}$	$3x10^{-5}$
Fluorene	$1x10^{-8}$	$1x10^{-5}$	$5x10^{-7}$	$4x10^{-9}$	$3x10^{-8}$	$1x10^{-5}$
Pyrene	$1x10^{-6}$	$4x10^{-4}$	$4x10^{-5}$	$2x10^{-8}$	$2x10^{-6}$	$4x10^{-4}$
Cadmium	$9x10^{-7}$	$5x10^{-5}$	$6x10^{-7}$	$4x10^{-8}$	$4x10^{-8}$	$5x10^{-5}$
Ingestion Cancer Risk- High-End						
Acenapthene						
Benzo(a)pyrene TEQ	$2x10^{-8}$	$2x10^{-5}$	$1x10^{-5}$	$3x10^{-10}$	$3x10^{-8}$	$3x10^{-5}$
Anthracene						
Fluoranthene						
Fluorene						
Pyrene						
Cadmium	$1x10^{-8}$	$7x10^{-7}$	$1x10^{-8}$	$2x10^{-10}$	$6x10^{-10}$	$7x10^{-7}$
Total Pathway Risk	**$3x10^{-8}$**	**$2x10^{-5}$**	**$1x10^{-5}$**	**$5x10^{-10}$**	**$3x10^{-8}$**	**$3x10^{-5}$**
Hazard Quotient -High End						
Acenapthene	$1x10^{-10}$	$1x10^{-6}$	$4x10^{-8}$	$2x10^{-10}$	$6x10^{-9}$	$1x10^{-6}$
Benzo(a)pyrene TEQ						
Anthracene	$3x10^{-12}$	$2x10^{-7}$	$4x10^{-9}$	$3x10^{-11}$	$2x10^{-10}$	$2x10^{-7}$
Fluoranthene	$4x10^{-8}$	$6x10^{-5}$	$2x10^{-6}$	$5x10^{-9}$	$8x10^{-7}$	$6x10^{-5}$
Fluorene	$3x10^{-8}$	$3x10^{-5}$	$1x10^{-6}$	$6x10^{-9}$	$7x10^{-8}$	$3x10^{-5}$
Pyrene	$2x10^{-6}$	$8x10^{-4}$	$8x10^{-5}$	$3x10^{-8}$	$4x10^{-6}$	$9x10^{-4}$
Cadmium	$2x10^{-6}$	$9x10^{-5}$	$1x10^{-6}$	$7x10^{-8}$	$8x10^{-8}$	$9x10^{-5}$

Table A-32. Multipathway Results for AK-Middletown

Substance	Soil	Produce	Animal Product	Water	Fish	Total Ingestion
Ingestion Cancer Risk- Central Tendency						
Acenapthene						
Benzo(a)pyrene TEQ	$3x10^{-9}$	$1x10^{-6}$	$1x10^{-6}$	$7x10^{-10}$	$5x10^{-8}$	$2x10^{-6}$
Anthracene						
Fluoranthene						
Fluorene						
Pyrene						
Cadmium	$8x10^{-10}$	$4x10^{-8}$	$5x10^{-10}$	$9x10^{-10}$	$2x10^{-9}$	$4x10^{-8}$
Total Pathway Risk	**$4x10^{-9}$**	**$1x10^{-6}$**	**$1x10^{-6}$**	**$2x10^{-9}$**	**$5x10^{-8}$**	**$2x10^{-6}$**
Hazard Quotient-Central Tendency						
Acenapthene	$3x10^{-11}$	$3x10^{-7}$	$1x10^{-8}$	$5x10^{-10}$	$1x10^{-8}$	$3x10^{-7}$
Benzo(a)pyrene TEQ						
Anthracene	$5x10^{-13}$	$5x10^{-8}$	$1x10^{-9}$	$7x10^{-11}$	$3x10^{-10}$	$5x10^{-8}$
Fluoranthene	$1x10^{-8}$	$8x10^{-6}$	$4x10^{-7}$	$3x10^{-8}$	$4x10^{-6}$	$1x10^{-5}$
Fluorene	$6x10^{-9}$	$5x10^{-6}$	$2x10^{-7}$	$5x10^{-8}$	$5x10^{-7}$	$6x10^{-6}$
Pyrene	$4x10^{-7}$	$1x10^{-4}$	$1x10^{-5}$	$2x10^{-7}$	$2x10^{-5}$	$1x10^{-4}$
Cadmium	$2x10^{-7}$	$1x10^{-5}$	$2x10^{-7}$	$5x10^{-7}$	$4x10^{-7}$	$1x10^{-5}$
Ingestion Cancer Risk- High-End						
Acenapthene						
Benzo(a)pyrene TEQ	$1x10^{-8}$	$7x10^{-6}$	$5x10^{-6}$	$3x10^{-9}$	$2x10^{-7}$	$1x10^{-5}$
Anthracene						
Fluoranthene						
Fluorene						
Pyrene						
Cadmium	$4x10^{-9}$	$2x10^{-7}$	$3x10^{-9}$	$3x10^{-9}$	$7x10^{-9}$	$2x10^{-7}$
Total Pathway Risk	**$1x10^{-8}$**	**$7x10^{-6}$**	**$5x10^{-6}$**	**$6x10^{-9}$**	**$2x10^{-7}$**	**$1x10^{-5}$**
Hazard Quotient -High End						
Acenapthene	$5x10^{-11}$	$7x10^{-7}$	$3x10^{-8}$	$9x10^{-10}$	$2x10^{-8}$	$8x10^{-7}$
Benzo(a)pyrene TEQ						
Anthracene	$1x10^{-12}$	$1x10^{-7}$	$3x10^{-9}$	$1x10^{-10}$	$7x10^{-10}$	$1x10^{-7}$
Fluoranthene	$2x10^{-8}$	$2x10^{-5}$	$1x10^{-6}$	$5x10^{-8}$	$8x10^{-6}$	$3x10^{-5}$
Fluorene	$1x10^{-8}$	$1x10^{-5}$	$4x10^{-7}$	$9x10^{-8}$	$1x10^{-6}$	$1x10^{-5}$
Pyrene	$8x10^{-7}$	$2x10^{-4}$	$3x10^{-5}$	$4x10^{-7}$	$5x10^{-5}$	$3x10^{-4}$
Cadmium	5x10-7	$2x10^{-5}$	$4x10^{-7}$	$8x10^{-7}$	$1x10^{-6}$	$2x10^{-5}$

Table A-33. Multipathway Results for Erie Coke

Substance	Soil	Produce	Animal Product	Water	Fish	Total Ingestion
Ingestion Cancer Risk- Central Tendency						
Acenapthene						
Benzo(a)pyrene TEQ	2x10^{-10}	1x10^{-7}	1x10^{-7}	8x10^{-10}	6x10^{-8}	3x10^{-7}
Anthracene						
Fluoranthene						
Fluorene						
Pyrene						
Cadmium	8x10^{-11}	4x10^{-9}	6x10^{-11}	7x10^{-11}	1x10^{-10}	4x10^{-9}
Total Pathway Risk	**3x10^{-10}**	**1x10^{-7}**	**1x10^{-7}**	**9x10^{-10}**	**6x10^{-8}**	**3x10^{-7}**
Hazard Quotient-Central Tendency						
Acenapthene	7x10^{-13}	6x10^{-9}	2x10^{-10}	1x10^{-10}	2x10^{-9}	9x10^{-9}
Benzo(a)pyrene TEQ						
Anthracene	6x10^{-14}	5x10^{-9}	1x10^{-10}	9x10^{-11}	4x10^{-10}	6x10^{-9}
Fluoranthene	5x10^{-10}	3x10^{-7}	2x10^{-8}	1x10^{-8}	1x10^{-6}	2x10^{-6}
Fluorene	3x10^{-10}	3x10^{-7}	1x10^{-8}	2x10^{-8}	2x10^{-7}	5x10^{-7}
Pyrene	4x10^{-8}	8x10^{-6}	9x10^{-7}	7x10^{-8}	6x10^{-6}	2x10^{-5}
Cadmium	2x10^{-8}	1x10^{-6}	2x10^{-8}	4x10^{-8}	4x10^{-8}	1x10^{-6}
Ingestion Cancer Risk- High-End						
Acenapthene						
Benzo(a)pyrene TEQ	1x10^{-9}	5x10^{-7}	5x10^{-7}	3x10^{-9}	3x10^{-7}	1x10^{-6}
Anthracene						
Fluoranthene						
Fluorene						
Pyrene						
Cadmium	3x10^{-10}	2x10^{-8}	3x10^{-10}	2x10^{-10}	6x10^{-10}	2x10^{-8}
Total Pathway Risk	**1x10^{-9}**	**5x10^{-7}**	**5x10^{-7}**	**3x10^{-9}**	**3x10^{-7}**	**1x10^{-6}**
Hazard Quotient -High End						
Acenapthene	1x10^{-12}	1x10^{-8}	5x10^{-10}	2x10^{-10}	5x10^{-9}	2x10^{-8}
Benzo(a)pyrene TEQ						
Anthracene	1x10^{-13}	1x10^{-8}	2x10^{-10}	1x10^{-10}	9x10^{-10}	1x10^{-8}
Fluoranthene	9x10^{-10}	7x10^{-7}	4x10^{-8}	2x10^{-8}	3x10^{-6}	3x10^{-6}
Fluorene	6x10^{-10}	6x10^{-7}	2x10^{-8}	3x10^{-8}	4x10^{-7}	1x10^{-6}
Pyrene	9x10^{-8}	2x10^{-5}	2x10^{-6}	1x10^{-7}	1x10^{-5}	3x10^{-5}
Cadmium	5x10^{-8}	2x10^{-6}	4x10^{-8}	7x10^{-8}	9x10^{-8}	3x10^{-6}

Table A-34. Multipathway Results for Tonawanda

Substance	Soil	Produce	Animal Product	Water	Fish	Total Ingestion
Ingestion Cancer Risk- Central Tendency						
Acenapthene						
Benzo(a)pyrene TEQ	$1x10^{-9}$	$6x10^{-7}$	$7x10^{-7}$	$3x10^{-11}$	$2x10^{-9}$	$1x10^{-6}$
Anthracene						
Fluoranthene						
Fluorene						
Pyrene						
Cadmium	$6x10^{-10}$	$3x10^{-8}$	$4x10^{-10}$	$1x10^{-11}$	$2x10^{-11}$	$3x10^{-8}$
Total Pathway Risk	**$2x10^{-9}$**	**$6x10^{-7}$**	**$7x10^{-7}$**	**$4x10^{-11}$**	**$2x10^{-9}$**	**$1x10^{-6}$**
Hazard Quotient-Central Tendency						
Acenapthene	$1x10^{-11}$	$1x10^{-7}$	$5x10^{-9}$	$2x10^{-11}$	$3x10^{-10}$	$1x10^{-7}$
Benzo(a)pyrene TEQ						
Anthracene	$8x10^{-13}$	$1x10^{-7}$	$3x10^{-9}$	$1x10^{-11}$	$6x10^{-11}$	$1x10^{-7}$
Fluoranthene	$5x10^{-9}$	$4x10^{-6}$	$2x10^{-7}$	$6x10^{-10}$	$6x10^{-8}$	$4x10^{-6}$
Fluorene	$3x10^{-9}$	$2x10^{-6}$	$8x10^{-8}$	$6x10^{-10}$	$5x10^{-9}$	$2x10^{-6}$
Pyrene	$2x10^{-7}$	$4x10^{-5}$	$5x10^{-6}$	$4x10^{-9}$	$4x10^{-7}$	$5x10^{-5}$
Cadmium	$2x10^{-7}$	$7x10^{-6}$	$1x10^{-7}$	$6x10^{-9}$	$6x10^{-9}$	$8x10^{-6}$
Ingestion Cancer Risk- High-End						
Acenapthene						
Benzo(a)pyrene TEQ	$6x10^{-9}$	$3x10^{-6}$	$3x10^{-6}$	$9x10^{-11}$	$9x10^{-9}$	$6x10^{-6}$
Anthracene						
Fluoranthene						
Fluorene						
Pyrene						
Cadmium	$2x10^{-9}$	$1x10^{-7}$	$2x10^{-9}$	$4x10^{-11}$	$9x10^{-11}$	$1x10^{-7}$
Total Pathway Risk	**$9x10^{-9}$**	**$3x10^{-6}$**	**$3x10^{-6}$**	**$1x10^{-10}$**	**$9x10^{-9}$**	**$6x10^{-6}$**
Hazard Quotient -High End						
Acenapthene	$2x10^{-11}$	$3x10^{-7}$	$1x10^{-8}$	$3x10^{-11}$	$7x10^{-10}$	$3x10^{-7}$
Benzo(a)pyrene TEQ						
Anthracene	$2x10^{-12}$	$3x10^{-7}$	$6x10^{-9}$	$2x10^{-11}$	$1x10^{-10}$	$3x10^{-7}$
Fluoranthene	$1x10^{-8}$	$9x10^{-6}$	$6x10^{-7}$	$9x10^{-10}$	$1x10^{-7}$	$1x10^{-5}$
Fluorene	$6x10^{-9}$	$5x10^{-6}$	$2x10^{-7}$	$9x10^{-10}$	$1x10^{-8}$	$5x10^{-6}$
Pyrene	$5x10^{-7}$	$9x10^{-5}$	$1x10^{-5}$	$7x10^{-9}$	$8x10^{-7}$	$1x10^{-4}$
Cadmium	$3x10^{-7}$	$1x10^{-5}$	$3x10^{-7}$	$1x10^{-8}$	$1x10^{-8}$	$2x10^{-5}$

Screening Ecological Risk Assessment

Source of Screening Values

Aquatic Biota

Most of the surface water screening values for aquatic biota were taken from Suter and Tsao (1996). For those aquatic contaminants without screening values in Suter and Tsao (1996), U.S.EPA's (2000a) aquatic toxicity data base, AQUIRE, and other on-line and library sources were searched to identify possible screening values. In order of preference, the types of surface water screening values selected for this analysis included the following:

- EPA water quality criteria for the protection of aquatic life.
- EPA Tier 2 values derived by Suter and Tsao (1996) using the methods described in EPA's *Proposed Water Quality Guidance for the Great Lakes System*. Tier 2 values are similar to U.S.EPA water quality criteria, except they are derived with fewer data.
- EPA Region IV values. These screening values are published by EPA Region IV, Atlanta, Georgia (Suter and Tsao 1996). They are used for screening-level risk assessments at hazardous waste sites.
- Lowest chronic values. These are the lowest chronic values [i.e., geometric means of no-observed effects concentrations (NOECs) and lowest observed effects concentrations (LOECs)] derived from chronic toxicity tests reported in the literature.
- For HAPs without chronic toxicity data, the lowest available acute toxicity endpoint, such as the LC_{50} (concentration expected to be lethal to 50% of animals) or EC_{50} (concentration expected to affect 50% of animals), was divided by 10 to estimate the chronic value (Suter and Tsao 1996).

For metals with hardness-dependent toxicity (i.e., cadmium and lead), the screening levels were adjusted for a hardness of 100 mg/L as $CaCO_3$.

Sediments

The sediment screening levels for aquatic life were extracted from Haines et al. (2000) and Jones et al. (1997). In order of preference, the types of sediment screening levels selected for this analysis included the following:

- Equilibrium partitioning (EqP) screening values. Equilibrium partitioning is the method chosen by EPA for developing sediment quality criteria for nonionic organic chemicals. This method estimates the sediment pore-water concentration of the chemical based on its partitioning between particulate and ionic forms, which is highly dependent on the concentration of organic carbon in the sediments. The EqP approach requires a surface water quality screening value, an organic carbon partitioning factor, and a measured or assumed organic carbon concentration.

The sediment screening value is the total concentration of the chemical estimated to produce a pore-water concentration equal to the surface water screening value. The surface water screening values used to derive the sediment screening values may include any of the types of surface water screening values discussed above, but primarily include

  - EPA chronic water quality criteria,
  - EPA Tier 2 values,
  - Less conservative chronic values, and
  - Lowest aquatic chronic values.

- National Atmospheric and Oceanic Administration (NOAA) Benchmarks. These benchmarks are based on analyses of the EqP approach, spiked sediment toxicity test data, and synoptically collected chemical and biological data from field surveys. Chemical concentrations observed or predicted to be associated with biological effects were ranked, and the 10th percentile ER-L (Effects Range-Low) and median ER-M (Effects Range-Median) were identified (Haines et al. 2000).

- Florida Department of Environmental Protection (FDEP) Benchmarks. The FDEP approach is similar to the NOAA approach. Similar data were used to estimate Threshold Effects Levels (TELs) and Probable Effects Levels (PELs). Unlike the ER-Ls and ER-Ms, however, the TELs and PELs also incorporate no adverse biological effects data. Specifically, the TEL is the geometric mean of the 15th percentile in the effects data and the 50th percentile in the no effects data. The PEL is the geometric mean of the 50th percentile in the effects data set and the 85th percentile in the no effects data set (Haines et al. 2000).

- Ontario Ministry of the Environment (OMOE) Sediment Quality Guidelines. The OMOE lowest effect level (Low) is the level at which actual ecotoxic effects become apparent. The OMOE severe effect level (Severe) represents contaminant levels that could potentially eliminate most of the benthic organisms (Haines et al. 2000).

A general limitation for all sediment screening values is that the bioavailability and toxicity of chemicals in sediments depends on a variety of site-specific factors and, therefore, are difficult to predict accurately. These factors are primarily chemical and physical factors that control the solubility of the chemicals in sediment pore water and in the overlying surface water. The percentage of chemicals in sediments that is bioavailable can range from 0 to 100%. Thus, measurements of bulk HAP concentrations in sediments are not accurate predictors of the HAP's biological and ecological effects. Estimates of sediment pore water concentrations are preferred. When properly used, sediment screening values identify sediments of potential concern and the HAPs that may be toxic to aquatic life. For such HAPs, actual effects should be confirmed with sediment toxicity tests and biological assessments of the benthic macroinvertebrate community inhabiting the sediments.

Vertebrate Wildlife

Wildlife screening values were obtained only for birds and mammals. We used bird and mammal wildlife screening values for ingestion of plants (herbivores), animals (carnivores), fish (piscivores) and water from Sample et al. (1996) for the HAPs for which they were available. The wildlife screening values are based on no observed adverse effects levels (NOAELs), which are maximum doses of the HAP estimated to cause no adverse toxicological effects. All wildlife screening values were calculated as the concentration of each chemical in each of these media that would be equivalent to the NOAEL at the species' food, water or soil ingestion rate or inhalation rate, with the assumption that each of these media and pathways was the only source of the chemical to the wildlife species.

We found no published wildlife screening values for air inhalation or soil ingestion. Consequently, air inhalation and soil ingestion screening values were estimated from the wildlife NOAELs. We used the same general procedures as in equations (4) (5) and (6) of Sample et al. (1996) used to derive their food and water ingestion screening values. Average body weights were obtained from Sample et al. (1996). The inhalation rates were obtained from U.S.EPA (1993b) and the soil ingestion rates were obtained from Suter et al. (2000). For inhalation screening values, cottontail rabbits and American woodcock were selected as the indicator species because they have a widespread distribution in the United States, they tended to have one of the smallest NOAELs for wildlife species in Sample et al. (1996), and data were available on their body weight and inhalation rates. For soil ingestion, short-tail shrews were selected as the indicator species because they have one of the highest soil ingestion rates for terrestrial mammals (13%, Suter et al. 2000). Bioavailability of the HAPs was assumed to be 100%.

Soil

Terrestrial plant screening values for soils are from Will and Suter (1995a) and the soil invertebrate, microbe and microbial processes screening values are from Will and Suter (1995b) and CCME (1997). The soil screening values for plants and soil invertebrates, microbes and microbial processes are concentrations estimated to be the 10th percentiles of the LOECs, which are analogous to NOAA's sediment screening values (Will and Suter 1995a, b). The screening value for hydrogen chloride is from USDA (2001). It is the threshold tolerance value for chloride for the most sensitive agricultural crop species.

Use of Toxicity Equivalents (TEQS)

Benzo(a)pyrene-TEQs (toxicity equivalents) were estimated in some media. For human health risk assessments, TEQs are used to estimate the toxicity of mixtures of PAHs. For the individual chemicals, the TEQs range from 1.0 to 0.001, with TEQs = 1.0 for benzo(a)pyrene and TEQs <1.0 for all the other PAHs. Unfortunately, due to the absence of toxicity data for aquatic and terrestrial plants and wildlife for many of these other PAHs the applicability of the TEQs for predicting ecological effects for these PAHs is unknown. The aquatic benchmarks, which are generally based on aquatic toxicity data generated using similar methods, indicate that benzo(a)pyrene is more toxic than the other PAHs. Therefore, the TEQ approach may be applicable to these PAHs. Because we do not have environmental toxicity data for most of the other PAHs, we used health-based benzo(a)pyrene-TEQs for the screening-level ecological risk assessment.

Uncertainty Discussion

For this screening-level ecological risk assessment, we list and discuss sources of uncertainty that may affect the results of the assessment. A quantitative assessment of uncertainty was not done. Assumptions and sources of uncertainty that would tend to increase the conservatism of this assessment included the following:

- The most conservative screening values readily available were selected. Some of these may overestimate the potential for toxicity to site-specific populations and communities.

- The bioavailability of all chemicals is assumed to be 100%, when in reality, site-specific bioavailability often is much less than 100%.

Assumptions and sources of uncertainty that would tend to decrease the conservatism of this assessment included the following:

- Some pathways and ecological receptors were not included in this analysis:
  - Aquatic organisms exposed via ingestion of HAP-contaminated food.
  - Benthic organisms exposed via ingestion of HAP-contaminated food.
  - Terrestrial invertebrates exposed via inhalation of HAPs in air or via ingestion of contaminated food, soil or water.
- Ecological screening values were not identified for some HAPs, media and receptors for some of the individual polycyclic aromatic hydrocarbons (PAHs) in some media and for some receptors, which precluded an evaluation of potential risks. These HAPs should still be considered chemicals of potential concern, unless other information can be used to justify disregarding them as chemicals of potential concern.
- Wildlife screening values were calculated as the concentration of each chemical in each medium that would be equivalent to the no observed adverse effects level at the species' water, food, or soil ingestion rates or inhalation rates, with the assumption that each of these media and pathways was the only source of the chemical to the wildlife species. In reality, the animals are exposed via multiple pathways.
- Background concentrations of the HAPs were not included in the calculations of exposure.
- The assessment assumes that the populations and communities at the four coke oven facilities were unaffected by other toxic chemicals or other environmental stressors. The presence of additional stressors may tend to increase the sensitivity of the communities to effects from the

HAPs emitted from the secondary lead smelters.

- We assumed that the screening values were protective of sensitive species, including threatened or endangered species. The actual sensitivities of virtually all threatened or endangered species to the HAPs are unknown.
- We assumed that the screening values are protective of ecosystem structure and function. The basis for this assumption is the assumption that ecosystem structure and function are unlikely to be adversely affected by a chemical, if the chemical has a very low potential for affecting sensitive species within the ecosystem. The degree of confidence in the validity and accuracy of the screening values depends on the extent of toxicological and other effects data available for each chemical and medium. For this screening-level risk assessment, we relied almost exclusively on published sources of screening values and made no attempt to validate their accuracy or validity.
- We used only single estimates of exposure concentrations derived using fate and transport models, not empirical measurements.

Table A-35. Tonawanda Coke Oven Ecological Screening Level Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients (HQ) [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo (a) pyrene	Indeno-123(cd) pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
PAH TEFs			0.1	0.01	0.1	0.01	1	0.1						
Air Concentration (ug/m^3)	5.1x10^{-6}	3.0x10^{-5}	2.9x10^{-5}	3.8x10^{-5}	2.2x10^{-5}	1.8x10^{-5}	2.3x10^{-5}	1.3x10^{-5}	9.6x10^{-6}	7.6x10^{-5}	3.5x10^{-5}	7.4x10^{-5}	5.6x10^{-5}	1.9x10^{-6}
Screening value: air inhalation by wildlife (ug/m^3)	76000	760					760		130000	10000	9500	57000	1900	1400
HQ	6.7x10^{-11}	3.9x10^{-8}					3.0x10^{-8}		7.2x10^{-11}	7.6x10^{-9}	3.6x10^{-9}	1.3x10^{-9}	3.0x10^{-8}	1.4x10^{-9}
Total Plant Concentration (ug/g)														
Grains	8.3x10^{-8}	8.3x10^{-7}	1.5x10^{-6}	2.9x10^{-6}	5.7x10^{-7}	1.6x10^{-6}	5.6x10^{-7}	1.6x10^{-7}	6.9x10^{-8}	4.4x10^{-6}	1.3x10^{-6}	2.4x10^{-5}	1.2x10^{-5}	4.6x10^{-7}
Legumes	3.0x10^{-6}	6.5x10^{-5}	2.1x10^{-5}	4.1x10^{-5}	1.9x10^{-5}	3.1x10^{-5}	3.9x10^{-5}	2.1x10^{-4}	1.4x10^{-5}	4.5x10^{-5}	2.4x10^{-5}	2.2x10^{-4}	7.9x10^{-5}	2.9x10^{-6}
Root vegetables (includes potatoes)	1.1x10^{-6}	5.0x10^{-5}	8.0x10^{-5}	1.6x10^{-4}	4.7x10^{-5}	1.3x10^{-4}	3.2x10^{-5}	2.4x10^{-5}	9.6x10^{-7}	1.9x10^{-4}	2.2x10^{-5}	6.0x10^{-4}	2.5x10^{-5}	9.4x10^{-7}
Fruits	1.8x10^{-5}	1.8x10^{-4}	1.0x10^{-4}	1.6x10^{-4}	8.6x10^{-5}	1.2x10^{-4}	1.3x10^{-4}	2.8x10^{-4}	8.7x10^{-5}	2.5x10^{-4}	1.2x10^{-4}	5.7x10^{-4}	3.9x10^{-4}	1.3x10^{-5}
Leafy vegetables (incl. fruiting vegetables	5.2x10^{-5}	4.6x10^{-3}	6.5x10^{-4}	1.9x10^{-3}	8x10^{-4}	1.5x10^{-3}	2.4x10^{-3}	2x10^{-2}	2.5x10^{-4}	8.2x10^{-4}	7.7x10^{-4}	1.4x10^{-2}	1.1x10^{-3}	3.83x10^{-5}
Screening value: herbivorous wildlife (ug/g)	200	2					2		350	26	25	150	3	3.6
HQ: Grains	4.2x10^{-10}	4.1x10^{-7}					2.8x10^{-7}		2.0x10^{-10}	1.7x10^{-7}	5.3x10^{-8}	1.6x10^{-7}	4.2x10^{-7}	1.3x10^{-7}
HQ: Legumes	1.5x10^{-8}	3.2x10^{-5}					1.9x10^{-5}		4.1x10^{-8}	1.7x10^{-6}	9.6x10^{-7}	1.5x10^{-6}	2.6x10^{-6}	8.3x10^{-7}
HQ: Root vegetables	5.7x10^{-9}	2.5x10^{-5}					1.6x10^{-5}		2.7x10^{-9}	7.2x10^{-6}	8.6x10^{-7}	4.0x10^{-6}	8.3x10^{-7}	2.6x10^{-7}
HQ: Fruits	8.9x10^{-8}	8.8x10^{-5}					6.4x10^{-5}		2.5x10^{-7}	9.4x10^{-6}	4.7x10^{-6}	3.8x10^{-6}	1.3x10^{-5}	3.7x10^{-6}
HQ: Leafy vegetables	2.6x10^{-7}	2.3x10^{-3}					1.2x10^{-3}		7.3x10^{-7}	3.1x10^{-5}	3.1x10^{-5}	9.3x10^{-5}	3.7x10^{-5}	1.1x10^{-5}
Animal Product Concentration (ug/g)														

Table A-35. Tonawanda Coke Oven Ecological Screening Level Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients (HQ) [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo (a) pyrene	Indeno-123(cd) pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
Beef	2.1x10^{-7}	2.2x10^{-4}	1.1x10^{-5}	3.4x10^{-5}	2.7x10^{-5}	5.0x10^{-5}	6.9x10^{-5}	1.5x10^{-3}	5.5x10^{-7}	6.9x10^{-6}	2.1x10^{-6}	1.1x10^{-4}	1.0x10^{-5}	1.5x10^{-7}
Pork	2.4x10^{-8}	4.2x10^{-4}	9.6x10^{-6}	3.2x10^{-5}	3.7x10^{-5}	9.1x10^{-5}	7.5x10^{-5}	3.4x10^{-3}	3.6x10^{-8}	2.0x10^{-6}	2.3x10^{-7}	3.8x10^{-5}	3.8x10^{-6}	1.9x10^{-8}
Screening value: carnivorous wildlife (ug/g)	290	2.9					2.9		510	38	36	220	4.2	5.1
HQ: Beef	7.1x10^{-10}	7.7x10^{-5}					2.4x10^{-5}		1.1x10^{-9}	1.8x10^{-7}	5.9x10^{-8}	4.8x10^{-7}	2.5x10^{-6}	2.9x10^{-8}
HQ: Pork	8.2x10^{-11}	1.4x10^{-4}					2.6x10^{-5}		7.0x10^{-11}	5.2x10^{-8}	6.3x10^{-9}	1.7x10^{-7}	9.1x10^{-7}	3.8x10^{-9}
Terrestrial Soil Concentrations (ug/g)														
Tilled Soil	8.2x10^{-7}	7.1x10^{-5}	7.6x10^{-5}	1.5x10^{-4}	5.6x10^{-5}	1.6x10^{-4}	5.0x10^{-5}	4.0x10^{-5}	3.5x10^{-7}	9.8x10^{-5}	8.7x10^{-6}	4.9x10^{-4}	1.4x10^{-3}	7.4x10^{-6}
Non-tilled Soil	9.0x10^{-7}	1.3x10^{-3}	8.3x10^{-4}	2.2x10^{-3}	7.9x10^{-4}	2.8x10^{-3}	9.6x10^{-4}	7.9x10^{-4}	3.6x10^{-7}	3.0x10^{-4}	1.6x10^{-4}	1.0x10^{-2}	2.9x10^{-2}	2.4x10^{-4}
Screening value: plants (ug/g)									20				50	3
HQ: Till Soil									1.7x10^{-8}				2.8x10^{-5}	2.4x10^{-6}
HQ: Non-tilled Soil									1.8x10^{-8}				5.9x10^{-4}	7.8x10^{-5}
Screening value: earthworms and microbial processes (ug/g)		7x10^{-1}								100	30		500	20
HQ: Tilled Soil		1.0x10^{-4}								9.8x10^{-7}	2.9x10^{-7}		2.8x10^{-6}	3.7x10^{-7}
HQ: Non-tilled Soil		1.8x10^{-3}								3.0x10^{-6}	5.5x10^{-6}		5.9x10^{-5}	1.2x10^{-5}
Screening value: vertebrates (ug/g)	1500	15					15		2700	2x10^{2}	190	1100	230	28
HQ: Tilled Soil	5.4x10^{-10}	4.6x10^{-6}					3.3x10^{-6}		1.3x10^{-10}	4.8x10^{-7}	4.6x10^{-8}	4.3x10^{-7}	6.1x10^{-6}	2.6x10^{-7}
HQ: Non-tilled Soil	5.9x10^{-10}	8.2x10^{-5}					6.3x10^{-5}		1.4x10^{-10}	1.5x10^{-6}	8.6x10^{-7}	8.7x10^{-6}	1.3x10^{-4}	8.4x10^{-6}

Table A-35. Tonawanda Coke Oven Ecological Screening Level Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients (HQ) [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo (a) pyrene	Indeno-123(cd) pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
Fish Concentrations (mg/g)														
Total HAP in fish	$1.3x10^{-10}$	$7.9x10^{-9}$	$2.9x10^{-9}$	$5.8x10^{-9}$	$3.8x10^{-9}$	$7.2x10^{-9}$	$6.5x10^{-9}$	$6.2x10^{-9}$	$1.3x10^{-10}$	$1.8x10^{-8}$	$1.4x10^{-9}$	$7.7x10^{-8}$	$2.6x10^{-11}$	$3.9x10^{-11}$
Screening value: piscivorous wildlife (mg/g)	$2.2x10^{-1}$	$2.2x10^{-3}$					$2.2x10^{-3}$		$3.9x10^{-1}$	$2.9x10^{-2}$	$2.8x10^{-2}$	$1.7x10^{-1}$	$2.2x10^{-3}$	$2.9x10^{-3}$
HQ	$6.1x10^{-10}$	$3.6x10^{-6}$					$2.9x10^{-6}$		$3.3x10^{-10}$	$6.2x10^{-7}$	$5.0x10^{-8}$	$4.7x10^{-7}$	$1.2x10^{-8}$	$1.4x10^{-8}$
Waterbody														
Total HAP in water column (ng/L)	$5.2x10^{-5}$		$5.6x10^{-4}$	$9.6x10^{-4}$	$3.8x10^{-4}$	$7.3x10^{-4}$	$6.5x10^{-4}$	$4.7x10^{-4}$	$2.1x10^{-4}$	$1.1x10^{-3}$	$1.1x10^{-3}$	$6.5x10^{-3}$	$3.3x10^{-3}$	$1.6x10^{-4}$
Screening value: wildlife (ng/L)	$2.3x10^{8}$	$2.3x10^{6}$					$2.3x10^{6}$		$4.0x10^{8}$	$3.0x10^{7}$	$2.9x10^{7}$	$1.7x10^{8}$	$4.9x10^{6}$	$4.1x10^{6}$
HQ	$2.3x10^{-13}$						$2.8x10^{-10}$		$5.1x10^{-13}$	$3.8x10^{-11}$	$4.0x10^{-11}$	$3.7x10^{-11}$	$6.7x10^{-10}$	$3.9x10^{-11}$
Total dissolved HAP in water (ng/L)	$5.2x10^{-5}$		$5.6x10^{-4}$	$9.6x10^{-4}$	$3.8x10^{-4}$	$7.3x10^{-4}$	$6.5x10^{-4}$	$4.7x10^{-4}$	$2.1x10^{-4}$	$1.1x10^{-3}$	$1.1x10^{-3}$	$6.5x10^{-3}$	$3.3x10^{-3}$	$1.6x10^{-4}$
Screening value: aquatic life (ng/L)	730	14	30	6		140	14		23000	6200	3900	25	3200	1100
HQ	$7.1x10^{-8}$		$1.9x10^{-5}$	$1.6x10^{-4}$		$5.2x10^{-6}$	$4.6x10^{-5}$		$9.0x10^{-9}$	$1.9x10^{-7}$	$2.9x10^{-7}$	$2.6x10^{-4}$	$1.0x10^{-6}$	$1.5x10^{-7}$
Total HAP in benthos (ng/g)	$5.0x10^{-5}$		$6.4x10^{-3}$	$1.3x10^{-2}$	$1.8x10^{-2}$	$3.3x10^{-2}$	$3.6x10^{-2}$	$1.1x10^{-1}$	$4.3x10^{-5}$	$2.3x10^{-3}$	$3.7x10^{-4}$	$1.8x10^{-2}$	$3.0x10^{-3}$	$1.4x10^{-5}$
Screening value: benthic aquatic life (ng/g)	20	9.6	4	9	300	2.6	9.6	$1x10^{1}$	10	20	10	20	23000	200
HQ	$2.5x10^{-6}$		$1.6x10^{-3}$	$1.4x10^{-3}$	$5.9x10^{-5}$	$1.3x10^{-2}$	$3.7x10^{-3}$	$1.0x10^{-2}$	$4.3x10^{-6}$	$1.2x10^{-4}$	$3.7x10^{-5}$	$9.1x10^{-4}$	$1.3x10^{-7}$	$7.0x10^{-8}$
Total Dissolved HAP in benthos (ng/L)	$5.2x10^{-5}$		$6.2x10^{-4}$	$1.1x10^{-3}$	$5.3x10^{-4}$	$9.8x10^{-4}$	$9.2x10^{-4}$	$6.7x10^{-4}$	$2.1x10^{-4}$	$1.2x10^{-3}$	$1.1x10^{-3}$	$6.6x10^{-3}$	$3.3x10^{-3}$	$1.6x10^{-4}$

Table A-35. Tonawanda Coke Oven Ecological Screening Level Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients (HQ) [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo (a) pyrene	Indeno-123(cd) pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
Screening value: aquatic life (ng/L)	730	14	30	6		140	14		23000	6200	3900	25	3200	1100
HQ	7.2x10^{-8}		2.1x10^{-5}	1.8x10^{-4}		7.0x10^{-6}	6.6x10^{-5}		9.0x10^{-9}	1.9x10^{-7}	2.9x10^{-7}	2.7x10^{-4}	1.0x10^{-6}	1.5x10^{-7}
Watershed														
HAP in watershed (ng/g)	1.6x10^{-2}		14	28	16	35	32	30	6.7x10^{-3}	4.9	1.5	75	76	31
Screening value: plants (ug/g)									20				50	30
HQ									3.3x10^{-7}				1.5x10^{-3}	1.0x10^{-4}
Screening value: earthworms and microbial processes (ug/g)		7.0x10^{-1}								100	30		500	20
HQ										4.9x10^{-5}	5.0x10^{-5}		1.5x10^{-4}	1.5x10^{-5}
Screening value: vertebrates (ug/g)	1500	15					15		2700	200	190	1100	230	28
HQ	1x10^{-8}						2.1x10^{-3}		2.5x10^{-9}	2.4x10^{-5}	7.9x10^{-6}	6.5x10^{-5}	3.4x10^{-4}	1.1x10^{-5}

[1] See Tables 3-8 and 3-9 for more information on the screening values used

[2] HQ = media concentrations/ screening values

Table A-36. AK-Ashland Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
PAH TEFs			.1	.01	.1	.01	1	.1						
Air Concentration (ug/m^3)	$7.1x10^{-5}$	$2.1x10^{-4}$	$2.1x10^{-4}$	$2.9x10^{-4}$	$1.7x10^{-4}$	$1.3x10^{-4}$	$1.6x10^{-4}$	$9.7x10^{-5}$	$5.9x10^{-5}$	$5.9x10^{-4}$	$3.0x10^{-4}$	$5.7x10^{-4}$	$5.4x10^{-4}$	$1.8x10^{-5}$
Screening value: air inhalation by wildlife (ug/m^3)	76000	760					760		130000	10000	9500	57000	1900	1400
HQ	$9.4x10^{-10}$	$2.8x10^{-7}$					$2.1x10^{-7}$		$4.4x10^{-10}$	$5.8x10^{-8}$	$3.1x10^{-8}$	$1.0x10^{-8}$	$2.9x10^{-7}$	$1.3x10^{-8}$
Total Plant Concentration (ug/g)														
Grains	$5.6x10^{-7}$	$3.2x10^{-6}$	$5.7x10^{-6}$	$1.1x10^{-5}$	$2.2x10^{-6}$	$6.8x10^{-6}$	$2.1x10^{-6}$	$7.2x10^{-7}$	$1.0x10^{-7}$	$1.6x10^{-5}$	$5.9x10^{-6}$	$1.1x10^{-4}$	$7.1x10^{-5}$	$2.6x10^{-6}$
Legumes	$1.2x10^{-5}$	$3.9x10^{-4}$	$7.6x10^{-5}$	$2.0x10^{-4}$	$8.4x10^{-5}$	$1.7x10^{-4}$	$2.1x10^{-4}$	$1.6x10^{-3}$	$1.0x10^{-5}$	$1.2x10^{-4}$	$9.5x10^{-5}$	$1.4x10^{-3}$	$4.8x10^{-4}$	$1.8x10^{-5}$
Root vegetables (includes potatoes)	$3.1x10^{-5}$	$7.6x10^{-4}$	$1.2x10^{-3}$	$2.5x10^{-3}$	$7.1x10^{-4}$	$2.2x10^{-3}$	$4.8x10^{-4}$	$4.4x10^{-4}$	$5.8x10^{-6}$	$2.9x10^{-3}$	$3.9x10^{-4}$	$1.0x10^{-2}$	$1.4x10^{-4}$	$5.4x10^{-6}$
Fruits	$7.1x10^{-5}$	$8.1x10^{-4}$	$3.0x10^{-4}$	$6.0x10^{-4}$	$2.9x10^{-4}$	$5.6x10^{-4}$	$5.5x10^{-4}$	$1.9x10^{-3}$	$6.0x10^{-5}$	$5.8x10^{-4}$	$3.5x10^{-4}$	$3.0x10^{-3}$	$2.4x10^{-3}$	$8.2x10^{-5}$
Leafy vegetables (incl. fruiting vegetables)	$2.1x10^{-4}$	$3.2x10^{-2}$	$3.5x10^{-3}$	$1.3x10^{-2}$	$5.0x10^{-3}$	$1.0x10^{-2}$	$1.6x10^{-2}$	$1.5x10^{-1}$	$1.8x10^{-4}$	$2.4x10^{-3}$	$4.8x10^{-3}$	$1.0x10^{-1}$	$6.8x10^{-3}$	$2.3x10^{-4}$
Screening value: herbivorous wildlife (ug/g)	200	2					2		350	26	25	150	30	3.6
HQ: Grains	$2.8x10^{-9}$	$1.6x10^{-6}$					$1.1x10^{-6}$		$3.0x10^{-10}$	$6.2x10^{-7}$	$2.4x10^{-7}$	$7.1x10^{-7}$	$2.4x10^{-6}$	$7.2x10^{-7}$
HQ: Legumes	$6.1x10^{-8}$	$2.0x10^{-4}$					$1.1x10^{-4}$		$2.9x10^{-8}$	$4.4x10^{-6}$	$3.8x10^{-6}$	$9.4x10^{-6}$	$1.6x10^{-5}$	$5.0x10^{-6}$
HQ: Root vegetables (includes potatoes)	$1.5x10^{-7}$	$3.8x10^{-4}$					$2.4x10^{-4}$		$1.7x10^{-8}$	$1.1x10^{-4}$	$1.5x10^{-5}$	$7.0x10^{-5}$	$4.8x10^{-6}$	$1.5x10^{-6}$

Table A-36. AK-Ashland Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
HQ: Fruits	$3.5x10^{-7}$	$4.0x10^{-4}$					$2.7x10^{-4}$		$1.7x10^{-7}$	$2.2x10^{-5}$	$1.4x10^{-5}$	$2.0x10^{-5}$	$7.9x10^{-5}$	$2.3x10^{-5}$
HQ: Leafy vegetables (incl. fruiting vegetables)	$1.0x10^{-6}$	$1.6x10^{-2}$					$8.0x10^{-3}$		$5.0x10^{-7}$	$9.2x10^{-5}$	$1.9x10^{-4}$	$7.0x10^{-4}$	$2.3x10^{-4}$	$6.5x10^{-5}$
Animal Products Concentrations (ug/g)														
Beef	$8.3x10^{-7}$	$1.6x10^{-3}$	$6.0x10^{-5}$	$2.2x10^{-4}$	$1.6x10^{-4}$	$3.3x10^{-4}$	$4.5x10^{-4}$	$1.1x10^{-2}$	$3.8x10^{-7}$	$2.0x10^{-5}$	$1.3x10^{-5}$	$7.7x10^{-4}$	$6.1x10^{-5}$	$8.7x10^{-7}$
Pork	$4.9x10^{-8}$	$1.3x10^{-4}$	$6.3x10^{-6}$	$2.3x10^{-5}$	$1.5x10^{-5}$	$3.9x10^{-5}$	$3.9x10^{-5}$	$8.9x10^{-4}$	$2.1x10^{-8}$	$1.7x10^{-6}$	$9.9x10^{-7}$	$7.0x10^{-5}$	$2.2x10^{-5}$	$1.1x10^{-7}$
Screening value: carnivorous wildlife (ug/g)	290	2.9					2.9		510	38	36	220	4.2	5.1
HQ: Beef	$2.8x10^{-9}$	$5.5x10^{-4}$					$1.6x10^{-4}$		$7.4x10^{-10}$	$5.3x10^{-7}$	$3.5x10^{-7}$	$3.5x10^{-6}$	$1.5x10^{-5}$	$1.7x10^{-7}$
HQ: Pork	$1.7x10^{-10}$	$4.5x10^{-5}$					$1.3x10^{-5}$		$4.2x10^{-11}$	$4.4x10^{-8}$	$2.7x10^{-8}$	$3.2x10^{-7}$	$5.2x10^{-6}$	$2.2x10^{-8}$
Terrestrial Soil Concentrations (ug/g)														
Tilled Soil	$5.6x10^{-6}$	$2.7x10^{-4}$	$2.8x10^{-4}$	$6.0x10^{-4}$	$2.1x10^{-4}$	$6.7x10^{-4}$	$1.9x10^{-4}$	$1.8x10^{-4}$	$5.3x10^{-7}$	$3.7x10^{-4}$	$3.9x10^{-5}$	$2.1x10^{-3}$	$7.9x10^{-3}$	$4.2x10^{-5}$
Non-tilled Soil	$6.1x10^{-6}$	$4.8x10^{-3}$	$3.1x10^{-3}$	$8.8x10^{-3}$	$3.0x10^{-3}$	$1.2x10^{-2}$	$3.6x10^{-3}$	$3.6x10^{-3}$	$5.5x10^{-7}$	$1.1x10^{-3}$	$7.4x10^{-4}$	$4.4x10^{-2}$	$1.7x10^{-1}$	$1.3x10^{-3}$
Screening value: plants (ug/g)									20				50	3
HQ: Tilled Soil									$2.6x10^{-8}$				$1.6x10^{-4}$	$1.4x10^{-5}$
HQ: Non-tilled Soil									$2.7x10^{-8}$				$3.4x10^{-3}$	$4.5x10^{-4}$
Screening value: earthworms and microbial processes (ug/g)		$7x10^{-1}$								100	30		500	20
HQ: Tilled Soil		$3.9x10^{-4}$								$3.7x10^{-6}$	$1.3x10^{-6}$		$1.6x10^{-5}$	$2.1x10^{-6}$

Table A-36. AK-Ashland Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
HQ:Non-tilled Soil		6.9×10^{-3}								1.1×10^{-5}	2.5×10^{-5}		3.4×10^{-4}	6.7×10^{-5}
Screening value: vertebrates (ug/g)	1500	15					15		2700	200	190	1100	230	28
HQ: Tilled Soil	3.6×10^{-9}	1.8×10^{-5}					1.2×10^{-5}		2.0×10^{-10}	1.8×10^{-6}	2.0×10^{-7}	1.9×10^{-6}	3.5×10^{-5}	1.5×10^{-6}
HQ: Non-tilled Soil	4.0×10^{-9}	3.2×10^{-4}					2.4×10^{-4}		2.0×10^{-10}	5.6×10^{-6}	3.9×10^{-6}	3.8×10^{-5}	7.5×10^{-4}	4.8×10^{-5}
Fish Concentrations (mg/g)														
Total HAP in fish	1.1×10^{-9}	2.6×10^{-8}	1.4×10^{-8}	2.7×10^{-8}	1.6×10^{-8}	2.3×10^{-8}	2.1×10^{-8}	1.8×10^{-8}	1.9×10^{-10}	1.0×10^{-7}	9.3×10^{-9}	3.3×10^{-7}	1.7×10^{-10}	2.6×10^{-10}
Screening value: piscivorous wildlife (mg/g)	2.2×10^{-1}	2.2×10^{-3}					2.2×10^{-3}		3.9×10^{-1}	2.9×10^{-2}	2.8×10^{-2}	1.7×10^{-1}	2.2×10^{-3}	2.9×10^{-3}
HQ	4.9×10^{-9}	1.2×10^{-5}					9.5×10^{-6}		5.0×10^{-10}	3.6×10^{-6}	3.4×10^{-7}	2.0×10^{-6}	7.8×10^{-8}	9.0×10^{-8}
Water body														
Total HAP in Water Column, (ng/L)	4.1×10^{-4}		2.8×10^{-3}	4.4×10^{-3}	1.6×10^{-3}	2.3×10^{-3}	2.1×10^{-3}	1.3×10^{-3}	3.2×10^{-4}	6.7×10^{-3}	7.7×10^{-3}	2.8×10^{-2}	2.1×10^{-2}	1.0×10^{-3}
Screening value: wildlife (ng/L)	2.3×10^{8}	2.3×10^{6}					2.3×10^{6}		4.0×10^{8}	3.0×10^{7}	2.9×10^{7}	1.7×10^{8}	4.9×10^{6}	4.1×10^{6}
HQ	1.8×10^{-12}						9.1×10^{-10}		7.9×10^{-13}	2.2×10^{-10}	2.7×10^{-10}	1.6×10^{-10}	4.4×10^{-9}	2.6×10^{-10}
Dissolved HAP in water (ng/L)	4.1×10^{-4}		2.8×10^{-3}	4.4×10^{-3}	1.6×10^{-3}	2.3×10^{-3}	2.1×10^{-3}	1.3×10^{-3}	3.2×10^{-4}	6.7×10^{-3}	7.7×10^{-3}	2.8×10^{-2}	2.1×10^{-2}	1.0×10^{-3}
Screening value: aquatic life (ng/L)	730	14	30	6		140	14		23000	6200	3900	25	3200	1100
HQ	5.6×10^{-7}		9.2×10^{-5}	7.4×10^{-4}		1.6×10^{-5}	1.5×10^{-4}		1.4×10^{-8}	1.1×10^{-6}	2.0×10^{-6}	1.1×10^{-3}	6.7×10^{-6}	9.5×10^{-7}

Table A-36. AK-Ashland Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
Total HAP in benthos (ng/g)	$4.0x10^{-4}$		$3.2x10^{-2}$	$5.8x10^{-2}$	$7.3x10^{-2}$	$1.0x10^{-1}$	$1.1x10^{-1}$	$3.2x10^{-1}$	$6.7x10^{-5}$	$1.3x10^{-2}$	$2.5x10^{-3}$	$7.8x10^{-2}$	$2.0x10^{-2}$	$9.2x10^{-5}$
Screening value: benthic aquatic life (ng/g)	20	9.6	4	9	300	2.6	9.6	10	10	20	10	20	23000	200
HQ	$2.0x10^{-5}$		$7.9x10^{-3}$	$6.5x10^{-3}$	$2.4x10^{-4}$	$3.9x10^{-2}$	$1.2x10^{-2}$	$3.1x10^{-2}$	$6.7x10^{-6}$	$6.7x10^{-4}$	$2.5x10^{-4}$	$3.9x10^{-3}$	$8.5x10^{-7}$	$4.6x10^{-7}$
Dissolved HAP in benthos (ng/L)	$4.1x10^{-4}$		$3.0x10^{-3}$	$4.9x10^{-3}$	$2.2x10^{-3}$	$3.0x10^{-3}$	$2.9x10^{-3}$	$1.9x10^{-3}$	$3.2x10^{-4}$	$6.8x10^{-3}$	$7.7x10^{-3}$	$2.9x10^{-2}$	$2.1x10^{-2}$	$1.0x10^{-3}$
Screening value: aquatic life (ng/L)	730	14	30	6		140	14		23000	6200	3900	25	3200	1100
HQ	$5.7x10^{-7}$		$1.0x10^{-4}$	$8.1x10^{-4}$		$2.2x10^{-5}$	$2.1x10^{-4}$		$1.4x10^{-8}$	$1.1x10^{-6}$	$2.0x10^{-6}$	$1.1x10^{-3}$	$6.7x10^{-6}$	$9.5x10^{-7}$
Watershed														
HAP in watershed (ng/g)	$9.2x10^{-2}$		39	74	42	70	64	60	$7.2x10^{-3}$	17	5	160	210	$8.6x10^{-1}$
Screening value: plants (ug/g)									20				50	3
HQ									$3.6x10^{-7}$				$4.2x10^{-3}$	$2.9x10^{-4}$
Screening value: earthworms and microbial processes (ug/g)		$7.0x10^{-1}$								100	30		500	20
HQ										$1.7x10^{-1}$	$1.7x10^{-1}$		$4.2x10^{-4}$	$4.3x10^{-5}$
Screening value: vertebrates (ug/g)	1500	15					15		2700	200	190	1100	230	28

Table A-36. AK-Ashland Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
HQ	6.0×10^{-5}						4.2×10^{-3}		2.7×10^{-6}	8.3×10^{-2}	2.6×10^{-2}	1.4×10^{-1}	9.3×10^{-4}	3.0×10^{-5}

[1] See Tables 3-8 and 3-9 for more information on the screening values used

[2] HQ = media concentrations/ screening values

Table A-37. Erie Coke Oven Ecological Screening Risk Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
PAH TEFs			.1	.01	.1	.01	1	.1						
Air Concentration (ug/m$^{3)}$	6.9x10^{-7}	5.2x10^{-6}	4.8x10^{-6}	6.2x10^{-6}	3.7x10^{-6}	3.1x10^{-6}	4.0x10^{-6}	2.1x10^{-6}	2.8x10^{-6}	1.2x10^{-5}	6.0x10^{-6}	1.3x10^{-5}	7.0x10^{-6}	2.4x10^{-7}
Screening value: air inhalation by wildlife (ug/m^3)	76000	760					760		130000	10000	9500	57000	1900	1400
HQ	9x10^{-12}	6.8x10^{-9}					5.3x10^{-9}		2.1x10^{-11}	1.2x10^{-9}	6.3x10^{-10}	2.2x10^{-10}	3.8x10^{-9}	1.8x10^{-10}
Total Plant Concentration (ug/g)														
Grains	5.7x10^{-9}	1.3x10^{-7}	1.6x10^{-7}	3.4x10^{-7}	6.3x10^{-8}	3.2x10^{-7}	9.3x10^{-8}	3.3x10^{-8}	5.3x10^{-9}	3.8x10^{-7}	1.4x10^{-7}	4.7x10^{-6}	1.8x10^{-6}	6.7x10^{-8}
Legumes	1.3x10^{-7}	1.1x10^{-5}	2.4x10^{-6}	5.7x10^{-6}	2.5x10^{-6}	6.2x10^{-6}	7.1x10^{-6}	3.6x10^{-5}	5.6x10^{-7}	2.9x10^{-6}	2.5x10^{-6}	4.2x10^{-5}	1.3x10^{-5}	4.75x10^{-7}
Root vegetables (includes potatoes)	7.8x10^{-8}	7.6x10^{-6}	8.5x10^{-6}	1.8x10^{-5}	5.2x10^{-6}	2.6x10^{-5}	5.3x10^{-6}	5.0x10^{-6}	7.4x10^{-8}	1.7x10^{-5}	2.3x10^{-6}	1.2x10^{-4}	3.7x10^{-6}	1.4x10^{-7}
Fruits	7.7x10^{-7}	3.2x10^{-5}	1.0x10^{-5}	2.1x10^{-5}	1.0x10^{-5}	2.6x10^{-5}	2.4x10^{-5}	5.1x10^{-5}	3.3x10^{-6}	1.5x10^{-5}	1.0x10^{-5}	1.2x10^{-4}	6.4x10^{-5}	2.2x10^{-6}
Leafy vegetables (incl. fruiting vegetables)	2.2x10^{-6}	7.9x10^{-4}	9.0x10^{-5}	2.9x10^{-4}	1.2x10^{-4}	2.8x10^{-4}	4.3x10^{-4}	3.4x10^{-3}	9.8x10^{-6}	5.9x10^{-5}	1.1x10^{-4}	2.5x10^{-3}	1.8x10^{-4}	6.3x10^{-6}
Screening value: herbivorous wildlife (ug/g)	200	2					2		350	26	25	150	30	3.6
HQ: Grains	2.9x10^{-11}	6.3x10^{-8}					4.6x10^{-8}		1.5x10^{-11}	1.4x10^{-8}	5.6x10^{-9}	3.1x10^{-8}	6.1x10^{-8}	1.9x10^{-8}
HQ Legumes	6.6x10^{-10}	5.6x10^{-6}					3.6x10^{-6}		1.6x10^{-9}	1.1x10^{-7}	9.9x10^{-8}	2.8x10^{-7}	4.3x10^{-7}	1.3x10^{-7}

Table A-37. Erie Coke Oven Ecological Screening Risk Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
HQ: Root vegetables (includes potatoes)	3.9×10^{-10}	3.8×10^{-6}					2.6×10^{-6}		2.1×10^{-10}	6.3×10^{-7}	9.3×10^{-8}	7.7×10^{-7}	1.2×10^{-7}	3.8×10^{-8}
HQ: Fruits	3.8×10^{-9}	1.6×10^{-5}					1.2×10^{-5}		9.6×10^{-9}	5.7×10^{-7}	4.2×10^{-7}	8.0×10^{-7}	2.1×10^{-6}	6.1×10^{-7}
HQ: Leafy vegetables (incl. fruiting vegetables)	1.1×10^{-8}	3.9×10^{-4}					2.1×10^{-4}		2.8×10^{-8}	2.2×10^{-6}	4.2×10^{-6}	1.7×10^{-5}	6.1×10^{-6}	1.8×10^{-6}
Animal Products Concentration (ug/g)														
Beef	8.9×10^{-9}	3.7×10^{-5}	1.5×10^{-6}	5.3×10^{-6}	3.9×10^{-6}	9.2×10^{-6}	1.2×10^{-5}	2.4×10^{-4}	2.1×10^{-8}	5.0×10^{-7}	2.9×10^{-7}	1.9×10^{-5}	1.6×10^{-6}	2.3×10^{-8}
Pork	1.0×10^{-9}	6.9×10^{-5}	1.2×10^{-6}	4.5×10^{-6}	5.1×10^{-6}	1.7×10^{-5}	1.3×10^{-5}	5.5×10^{-4}	1.4×10^{-9}	1.6×10^{-7}	3.1×10^{-8}	6.8×10^{-6}	5.7×10^{-7}	2.9×10^{-9}
Screening value: carnivorous wildlife (ug/g)	290	29					29		510	38	36	220	4.2	5.1
HQ: Beef	3.1×10^{-11}	1.3×10^{-5}					4.2×10^{-6}		4.1×10^{-11}	1.3×10^{-8}	7.9×10^{-9}	8.7×10^{-8}	3.8×10^{-7}	4.5×10^{-9}
HQ: Pork	3.6×10^{-12}	2.4×10^{-5}					4.5×10^{-6}		2.7×10^{-12}	4.1×10^{-9}	8.7×10^{-10}	3.1×10^{-8}	1.3×10^{-7}	5.7×10^{-10}
Terrestrial Soil Concentrations (ug/g)														
Tilled Soil	5.7×10^{-8}	1.1×10^{-5}	8.1×10^{-6}	1.8×10^{-5}	6.3×10^{-6}	3.1×10^{-5}	8.4×10^{-5}	8.4×10^{-6}	2.7×10^{-8}	8.5×10^{-6}	9.3×10^{-7}	9.4×10^{-5}	2.0×10^{-4}	1.1×10^{-6}
Non-tilled Soil	6.2×10^{-8}	2.0×10^{-4}	8.8×10^{-5}	2.6×10^{-4}	8.8×10^{-5}	5.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	2.8×10^{-8}	2.6×10^{-5}	1.8×10^{-5}	1.9×10^{-3}	4.3×10^{-3}	3.4×10^{-5}
Screening value: plants (ug/g)									20				50	3
HQ: Tilled Soil									1.3×10^{-9}				4.1×10^{-6}	3.6×10^{-7}

Table A-37. Erie Coke Oven Ecological Screening Risk Assessment: Media Concentrations, Ecological Screening Values[1], and Hazard Quotients[2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
HQ: Non-tilled Soil									$1.4x10^{-9}$				$8.7x10^{-5}$	$1.1x10^{-5}$
Screening value: earthworms and microbial processes (ug/g)		$7x10^{-1}$								100	30		500	20
HQ_Tilled Soil		$1.6x10^{-5}$								$8.5x10^{-8}$	$3.1x10^{-8}$		$4.1x10^{-7}$	$5.4x10^{-8}$
HQ: Non-tilled Soil		$2.9x10^{-4}$								$2.6x10^{-7}$	$5.9x10^{-7}$		$8.7x10^{-6}$	$1.7x10^{-6}$
Screening value: vertebrates (ug/g)	1500	15					15		2700	200	190	1100	230	28
HQ: Tilled Soil	$3.7x10^{-11}$	$7.3x10^{-7}$					$5.5x10^{-7}$		$1.0x10^{-11}$	$4.2x10^{-8}$	$4.9x10^{-9}$	$8.2x10^{-8}$	$9.1x10^{-7}$	$3.8x10^{-8}$
HQ: Non-tilled Soil	$4.0x10^{-11}$	$1.3x10^{-5}$					$1.0x10^{-5}$		$1.0x10^{-11}$	$1.3x10^{-7}$	$9.2x10^{-8}$	$1.7x10^{-6}$	$1.9x10^{-5}$	$1.2x10^{-6}$
Fish Concentrations (mg/g)														
Total HAP in fish	$1.2x10^{-9}$	$1.7x10^{-6}$	$2.0x10^{-7}$	$9.5x10^{-7}$	$1.9x10^{-7}$	$2.2x10^{-6}$	$1.6x10^{-6}$	$8.3x10^{-7}$	$1.1x10^{-9}$	$6.2x10^{-7}$	$2.0x10^{-6}$	$1.2x10^{-4}$	$1.4x10^{-8}$	$3.7x10^{-8}$
Screening value: piscivorous wildlife (mg/g)	$2.2x10^{-1}$	$2.2x10^{-3}$					$2.2x10^{-3}$		$3.9x10^{-1}$	$2.9x10^{-2}$	$2.8x10^{-2}$	$1.7x10^{-1}$	$2.2x10^{-3}$	$2.9x10^{-3}$
HQ	$5.5x10^{-9}$	$7.8x10^{-4}$					$7.1x10^{-4}$		$2.8x10^{-9}$	$2.1x10^{-5}$	$7.2x10^{-5}$	$7.2x10^{-4}$	$6.4x10^{-6}$	$1.3x10^{-5}$
Water body														
Total HAP in Water Column (ng/L)	$4.6x10^{-4}$		$4.0x10^{-2}$	$1.6x10^{-1}$	$2.0x10^{-2}$	$2.3x10^{-2}$	$1.6x10^{-1}$	$7.0x10^{-2}$	$1.8x10^{-3}$	$3.9x10^{-2}$	1.7	10	1.8	$1.5x10^{-1}$

Table A-37. Erie Coke Oven Ecological Screening Risk Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
Screening value: wildlife (ng/L)	2.3x10^{8}	2.3x10^{6}					2.3x10^{6}		4.0x10^{8}	3x10^{7}	2.9x10^{7}	1.7x10^{8}	4.9x10^{6}	4.1x10^{6}
HQ	2.0x10^{-12}						7.0x10^{-8}		4.4x10^{-12}	1.3x10^{-9}	5.7x10^{-8}	5.8x10^{-8}	3.6x10^{-7}	3.6x10^{-8}
Dissolved HAP in water (ng/L)	4.6x10^{-4}		4.0x10^{-2}	1.6x10^{-1}	2.0x10^{-2}	2.2x10^{-1}	1.6x10^{-1}	6.3x10^{-2}	1.8x10^{-3}	3.9x10^{-2}	1.7	10	1.8	1.5x10^{-1}
Screening value: aquatic life (ng/L)	730	14	30	6		140	14		23000	6200	3900	25	3200	1100
HQ	6.3x10^{-7}		1.3x10^{-3}	2.6x10^{-2}		1.6x10^{-3}	1.1x10^{-2}		7.7x10^{-8}	6.4x10^{-6}	4.2x10^{-4}	4.0x10^{-1}	5.5x10^{-4}	1.3x10^{-4}
Total HAP in benthos (ng/g)[3]	4.6x10^{-4}		5.2x10^{-1}	2.4	1	1	9.2	4.4	3.7x10^{-4}	8.3x10^{-2}	5.4x10^{-1}	29	1.6	1.3x10^{-2}
Screening value: benthic aquatic life (ng/g)	20		4	9	300	2.6	9.6	10	10	20	10	20	23000	200
HQ[3]	2.3x10^{-5}		1.3x10^{-1}	2.7x10^{-1}	3.4x10^{-3}	.38	9.6x10^{-1}	.44	3.7x10^{-5}	4.1x10^{-3}	5.4x10^{-2}	1.5	7.0x10^{-5}	6.4x10^{-5}
Dissolved HAP in benthos (ng/L)	4.8x10^{-4}		5.0x10^{-2}	2.0x10^{-1}	3.1x10^{-2}	3.2x10^{-1}	2.4x10^{-1}	1.0x10^{-1}	1.8x10^{-3}	4.2x10^{-2}	1.7	11	1.8	1.5x10^{-1}
Screening value: aquatic life (ng/L)	730	14	30	6		140	14		23000	6200	3900	25	3200	1100
HQ	6.5x10^{-7}		1.7x10^{-3}	3.4x10^{-2}		2.3x10^{-3}	1.7x10^{-2}		7.7x10^{-8}	6.8x10^{-6}	4.3x10^{-4}	4.3x10^{-1}	5.5x10^{-4}	1.3x10^{-4}
Watershed														
HAP in watershed (ng/g)	6.5x10^{-4}		7.3x10^{-1}	1.4	7.8x10^{-1}	1.6	1.5	1.3	2.6x10^{-4}	2.6x10^{-1}	8.4x10^{-2}	3.4	2.5	1.0x10^{-2}

Table A-37. Erie Coke Oven Ecological Screening Risk Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123 (cd)pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
Screening value: plants (ug/g)									20				50	3
HQ									1.3×10^{-8}				5.0×10^{-5}	3.4×10^{-6}
Screening value: earthworms and microbial processes (ug/g)		7×10^{-1}								100	30		500	20
HQ										2.6×10^{-6}	2.8×10^{-5}		5.0×10^{-6}	5.1×10^{-7}
Screening value: vertebrates (ug/g)	1500	15					15		2700	200	190	1100	230	28
HQ	4.3×10^{-10}						1.0×10^{-4}		9.8×10^{-11}	1.3×10^{-6}	4.4×10^{-7}	3.0×10^{-6}	1.1×10^{-5}	3.6×10^{-7}

[1] See Tables 3-8 and 3-9 for more information on the screening values used

[2] HQ = media concentrations/ screening values

[3] The concentrations estimated in the Benthos environment in Lake Erie is based on an assumption of 100 % HAP bioavailability and that there is no movement of the water in the Lake. If that latter assumption is changed to reflect some back and forth flow of the water in the lake, (i.e., used the flow rate through the Niagara River as a long term average flow rate rather than zero), the benthic sediment values decrease so that there are no sediment values which exceed the screening values.

Table A-38. AK- Middletown Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123(cd) pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
PAH TEF			.1	.01	.1	.01	1	.1						
Air Concentration (ug/m^3)	1.7x10^{-5}	7.8x10^{-5}	7.3x10^{-5}	9.6x10^{-5}	5.7x10^{-5}	4.7x10-5	6.0 x10^{-5}	3.2x10^{-5}	1.4x10^{-5}	2.0x10^{-4}	1.0x10^{-4}	2.0x10^{-4}	1.2x10^{-4}	4.1x10^{-6}
Screening value: air inhalation by wildlife (ug/m^3)	76000	760					760		130000	10000	9500	57000	1900	1400
HQ	2.2x10^{-10}	1.0x10^{-7}					7.9x10^{-8}		1.0x10^{-10}	2.0x10^{-8}	1.0x10^{-8}	3.4x10^{-9}	6.5x10^{-8}	3.0x10^{-9}
Total Plant Concentration (ug/g)														
Grains	2.2x10^{-7}	1.5x10^{-6}	2.9x10^{-6}	5.3x10^{-6}	1.1x10^{-6}	2.5x10^{-6}	9.6x10^{-7}	2.4x10^{-7}	3.9x10^{-8}	8.7x10^{-6}	2.9x10^{-6}	4.1x10^{-5}	1.9x10^{-5}	6.8x10^{-7}
Legumes	7.0x10^{-6}	1.4x10^{-4}	3.9x10^{-5}	8.1x10^{-5}	3.7x10^{-5}	6.0x10^{-5}	8.3x10^{-5}	5.3x10^{-4}	5.9x10^{-6}	8.2x10^{-5}	5.0x10^{-5}	4.9x10^{-4}	1.1x10^{-4}	4.3x10^{-6}
Root vegetables (includes potatoes)	3.0x10^{-6}	8.8x10^{-5}	1.5x10^{-4}	2.9x10^{-4}	8.8x10^{-5}	2.1x10^{-4}	5.5x10^{-5}	3.7x10^{-5}	5.4x10^{-7}	3.8x10^{-4}	4.7x10^{-5}	1.0x10^{-3}	3.7x10^{-5}	1.4x10^{-6}
Fruits	4.2x10^{-5}	3.2x10^{-4}	1.7x10^{-4}	2.8x10^{-4}	1.5x10^{-4}	1.9x10^{-4}	2.2x10^{-4}	6.3x10^{-4}	3.6x10^{-5}	4.4x10^{-4}	2.2x10^{-4}	1.0x10^{-3}	5.5x10^{-4}	1.9x10^{-5}
Leafy vegetables (incl. fruiting vegetables)	1.2x10^{-4}	1.2x10^{-2}	1.4x10^{-3}	4.4x10^{-3}	1.8x10^{-3}	3.6x10^{-3}	6.0x10^{-3}	5.2x10^{-2}	1.0x10^{-4}	1.5x10^{-3}	1.9x10^{-3}	3.6x10^{-2}	1.6x10^{-3}	5.5x10^{-5}
Screening value: herbivorous wildlife (ug/g)	200	2					2		350	26	25	150	30	3.6
HQ: Grains	1.1x10^{-9}	7.3x10^{-7}					4.8x10^{-7}		1.1x10^{-10}	3.3x10^{-7}	1.2x10^{-7}	2.7x10^{-7}	6.2x10^{-7}	1.9x10^{-7}
HQ: Legumes	3.5x10^{-8}	7.2x10^{-5}					4.1x10^{-5}		1.7x10^{-8}	3.1x10^{-6}	2.0x10^{-6}	3.3x10^{-6}	3.8x10^{-6}	1.2x10^{-6}

Table A-38. AK- Middletown Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123(cd) pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
HQ: Root vegetables (includes potatoes)	1.5x10^{-8}	4.4x10^{-5}					2.7x10^{-5}		1.5x10^{-9}	1.4x10^{-5}	1.9x10^{-6}	6.7x10^{-6}	1.2x10^{-6}	3.9x10^{-7}
HQ: Fruits	2.1x10^{-7}	1.6x10^{-4}					1.1x10^{-4}		1.0x10^{-7}	1.7x10^{-5}	8.9x10^{-6}	7.0x10^{-6}	1.8x10^{-5}	5.3x10^{-6}
HQ: Leafy vegetables (incl. fruiting vegetables)	6.1x10^{-7}	5.8x10^{-3}					3.0x10^{-3}		3.0x10^{-7}	5.8x10^{-5}	7.6x10^{-5}	2.4x10^{-4}	5.3x10^{-5}	1.5x10^{-5}
Animal Products Concentration (ug/g)														
Beef	4.8x10^{-7}	5.6x10^{-4}	2.5x10^{-5}	7.9x10^{-5}	6.0x10^{-5}	1.2x10^{-4}	1.7x10^{-4}	3.8x10^{-3}	2.2x10^{-7}	1.3x10^{-5}	5.2x10^{-6}	2.7x10^{-4}	1.5x10^{-5}	2.2x10^{-7}
Pork	2.8x10^{-8}	4.6x10^{-5}	2.7x10^{-6}	8.8x10^{-6}	6.1x10^{-6}	1.4x10^{-5}	1.5x10^{-5}	3.0x10^{-4}	1.3x10^{-8}	9.8x10^{-7}	3.9x10^{-7}	2.5x10^{-5}	5.7x10^{-6}	2.9x10^{-8}
Screening value: carnivorous wildlife (ug/g)	290	2.9					2.9		510	38	36	220	4.2	5.1
HQ: Beef	1.7x10^{-9}	1.9x10^{-4}					5.8x10^{-5}		4.4x10^{-10}	3.4x10^{-7}	1.4x10^{-7}	1.2x10^{-6}	3.6x10^{-6}	4.3x10^{-8}
HQ: Pork	9.7x10^{-11}	1.6x10^{-5}					5.1x10^{-6}		2.5x10^{-11}	2.6x10^{-8}	1.1x10^{-8}	1.1x10^{-7}	1.4x10^{-6}	5.6x10^{-9}
Terrestrial Soil Concentrations (ug/g)														
Tilled Soil	2.1x10^{-6}	1.2x10^{-4}	1.5x10^{-4}	2.8x10^{-4}	1.1x10^{-4}	2.5x10^{-4}	8.7x10^{-5}	6.2x10^{-5}	2.0x10^{-7}	2.0x10^{-4}	1.9x10^{-5}	8.2x10^{-4}	2.1x10^{-3}	1.1x10^{-5}
Non-tilled Soil	2.3x10^{-6}	2.2x10^{-3}	1.6x10^{-3}	4.2x10^{-3}	1.5x10^{-3}	4.5x10^{-3}	1.7x10^{-3}	1.2x10^{-3}	2x10^{-7}	6x10^{-4}	3.6x10^{-4}	1.7x10^{-2}	4.4x10^{-2}	3.5x10^{-4}
Screening value: plants (ug/g)									20				50	3
HQ: Tilled Soil									9.9x10^{-9}				4.1x10^{-5}	3.7x10^{-6}
HQ: Non-tilled Soil									1.0x10^{-8}				8.8x10^{-4}	1.2x10^{-4}

Table A-38. AK- Middletown Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123(cd) pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
Screening value: earthworms and microbial processes (ug/g)		$7\text{x}10^{-1}$								100	30		500	20
HQ: Tilled Soil		$1.8\text{x}10^{-4}$								$2.0\text{x}10^{-6}$	$6.4\text{x}10^{-7}$		$4.1\text{x}10^{-6}$	$5.5\text{x}10^{-7}$
HQ: Non-tilled Soil		$3.1\text{x}10^{-3}$								$6.0\text{x}10^{-6}$	$1.2\text{x}10^{-5}$		$8.8\text{x}10^{-5}$	$1.8\text{x}10^{-5}$
Screening value: vertebrates (ug/g)	1500	15					15		2700	200	190	1100	230	28
HQ: Tilled Soil	$1.4\text{x}10^{-9}$	$8.1\text{x}10^{-6}$					$5.7\text{x}10^{-6}$		$7.4\text{x}10^{-11}$	$9.7\text{x}10^{-7}$	$1.0\text{x}10^{-7}$	$7.2\text{x}10^{-7}$	$9.2\text{x}10^{-6}$	$3.9\text{x}10^{-7}$
HQ: Non-tilled Soil	$1.5\text{x}10^{-9}$	$1.4\text{x}10^{-4}$					$1.1\text{x}10^{-4}$		$7.6\text{x}10^{-11}$	$3.0\text{x}10^{-6}$	$1.9\text{x}10^{-6}$	$1.5\text{x}10^{-5}$	$1.9\text{x}10^{-4}$	$1.2\text{x}10^{-5}$
Fish Concentrations														
Total HAP in fish (mg/g)	$4.2\text{x}10^{-9}$	$2.1\text{x}10^{-7}$	$1.5\text{x}10^{-7}$	$2.8\text{x}10^{-7}$	$1.2\text{x}10^{-7}$	$1.8\text{x}10^{-7}$	$1.7\text{x}10^{-7}$	$8.4\text{x}10^{-8}$	$6.7\text{x}10^{-10}$	$1.1\text{x}10^{-6}$	$1.3\text{x}10^{-7}$	$4.6\text{x}10^{-6}$	$2.1\text{x}10^{-9}$	$3.2\text{x}10^{-9}$
Screening value: piscivorous wildlife (mg/g)	$2.2\text{x}10^{-1}$	$2.2\text{x}10^{-3}$					$2.2\text{x}10^{-3}$		$3.9\text{x}10^{-1}$	$2.9\text{x}10^{-2}$	$2.8\text{x}10^{-2}$	$1.7\text{x}10^{-1}$	$2.2\text{x}10^{-3}$	$2.9\text{x}10^{-3}$
HQ	$1.9\text{x}10^{-8}$	$9.4\text{x}10^{-5}$					$7.6\text{x}10^{-5}$		$1.7\text{x}10^{-9}$	$3.7\text{x}10^{-5}$	$4.8\text{x}10^{-6}$	$2.8\text{x}10^{-5}$	$9.4\text{x}10^{-7}$	$1.1\text{x}10^{-6}$
Water body														
Total HAP in Water Column (ng/L)	$1.6\text{x}10^{-3}$		$2.9\text{x}10^{-2}$	$4.6\text{x}10^{-2}$	$1.2\text{x}10^{-2}$	$1.9\text{x}10^{-2}$	$1.7\text{x}10^{-2}$	$6.6\text{x}10^{-3}$	$1.1\text{x}10^{-3}$	$6.8\text{x}10^{-2}$	$1.1\text{x}10^{-1}$	$3.8\text{x}10^{-1}$	$2.6\text{x}10^{-1}$	$1.3\text{x}10^{-2}$
Screening value: wildlife (ng/L)	$2.3\text{x}10^{8}$	$2.3\text{x}10^{6}$					$2.3\text{x}10^{6}$		$4.0\text{x}10^{8}$	$3.0\text{x}10^{7}$	$2.9\text{x}10^{7}$	$1.7\text{x}10^{8}$	$4.9\text{x}10^{6}$	$4.1\text{x}10^{6}$

Table A-38. AK- Middletown Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123(cd) pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
HQ	7.0×10^{-12}						7.3×10^{-9}		2.7×10^{-12}	2.2×10^{-9}	3.8×10^{-9}	2.2×10^{-9}	5.3×10^{-8}	3.1×10^{-9}
Dissolved HAP in water (ng/L)	1.6×10^{-3}		2.9×10^{-2}	4.6×10^{-2}	1.2×10^{-2}	1.9×10^{-2}	1.7×10^{-2}	6.4×10^{-3}	1.1×10^{-3}	6.8×10^{-2}	1.1×10^{-1}	3.8×10^{-1}	2.6×10^{-1}	1.3×10^{-2}
Screening value: aquatic life (ng/L)	730	14	30	6		140	14		23000	6200	3900	25	3200	1100
HQ	2.2×10^{-6}		9.6×10^{-4}	7.6×10^{-3}		1.3×10^{-4}	1.2×10^{-3}		4.8×10^{-8}	1.1×10^{-5}	2.8×10^{-5}	1.5×10^{-2}	8.1×10^{-5}	1.2×10^{-5}
Total HAP in benthos (ng/g)	1.6×10^{-3}		3.4×10^{-1}	8.2×10^{-1}	5.5×10^{-1}	8.1×10^{-1}	8.9×10^{-1}	2.0x10	2.3×10^{-4}	1.4×10^{-1}	3.5×10^{-2}	1.1	2.4×10^{-1}	1.1×10^{-3}
Screening value: benthic aquatic life (ng/g)	20	9.6	4	9	300	2.6	9.6	10	10	20	10	20	23000	200
HQ	7.8×10^{-5}		8.5×10^{-2}	6.9×10^{-2}	1.8×10^{-3}	3.1×10^{-1}	9.2×10^{-2}	1.9×10^{-1}	2.3×10^{-5}	6.9×10^{-3}	3.5×10^{-3}	5.4×10^{-2}	1.0×10^{-5}	5.6×10^{-6}
Dissolved HAP in benthos (ng/L)	1.6×10^{-3}		3.2×10^{-2}	5.2×10^{-2}	1.6×10^{-2}	2.4×10^{-2}	2.3×10^{-2}	1.2×10^{-2}	1.1×10^{-3}	7.0×10^{-2}	1.1×10^{-1}	4.0×10^{-1}	2.6×10^{-1}	1.3×10^{-2}
Screening value: aquatic life (ng/L)	730	14	30	6		140	14		23000	6200	3900	25	3200	1100
HQ	2.3×10^{-6}		1.1×10^{-3}	8.6×10^{-3}		1.7×10^{-4}	1.6×10^{-3}		4.8×10^{-8}	1.1×10^{-5}	2.8×10^{-5}	1.6×10^{-2}	8.1×10^{-5}	1.2×10^{-5}
Watershed														
HAP in watershed (ng/g)	3.6×10^{-2}		18	33	19	32	31	26	2.8×10^{-3}	7.9	2.3	72	69	2.8×10^{-1}
Screening value: plants (ug/g)									20				50	3
HQ									1.4×10^{-7}				1.4×10^{-3}	9.4×10^{-5}

Table A-38. AK- Middletown Coke Oven Ecological Screening Assessment: Media Concentrations, Ecological Screening Values [1], and Hazard Quotients [2]

	Anthracene	Total TEF	Benzo(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(a) pyrene	Indeno-123(cd) pyrene	Acenaphthene	Fluoranthene	Fluorene	Pyrene	Lead	Cadmium
Screening value: earthworms and microbial processes (ug/g)		$7x10^{-1}$								100	30		500	20
HQ										$7.9x10^{-5}$	$7.8x10^{-5}$		$1.4x10^{-4}$	$1.4x10^{-5}$
Screening value: vertebrates (ug/g)	1500	15					15		2700	200	190	1100	230	28
HQ	$2.3x10^{-8}$						$2.1x10^{-3}$		$1.0x10^{-9}$	$3.9x10^{-5}$	$1.2x10^{-5}$	$6.3x10^{-5}$	$3.1x10^{-4}$	$1.0x10^{-5}$

[1] See Tables 3-8 and 3-9 for more information on the screening values used

[2] HQ = media concentrations/ screening values

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Appendix B: Hazard Identification and Dose Response

Table B-1 summarizes the chronic inhalation dose response information for coke oven emissions constituents and provides the constituent name, Chemical Abstract Service Registry Number (CASRN), inhalation URE ($(\mu g/m^3)^{-1}$), RfC (in units of mg/m^3), and reference for each of these dose response values.

Endpoints Assessed and Health Effects

The HAP released from coke ovens are associated with a variety of adverse health effects. These adverse health effects include chronic health disorders (e.g., cancers, blood disorders, damage to the central nervous system, and respiratory lesions) and acute health disorders (e.g., irritation of skin, eyes, and mucous membranes and depression of the central nervous system). The degree of adverse health effects experienced by exposed individuals can range from mild to severe. The extent and degree to which the health effects may be experienced depend on various factors, which have been considered to the extent feasible in the risk assessment. Those factors include:

- Pollutant-specific characteristics (e.g., toxicity, half-life in the environment, bioaccumulation, and persistence);
- Ambient concentrations observed in the area (e.g., as influenced by emission rates and meteorological conditions); and
- Frequency and duration of exposures

Given the round-the-clock (vs. batch) nature of coke oven processes, emissions are more continuous than episodic in nature. Consequently, analysis of acute (short-term) exposures was not part of this assessment. Rather, we focused on assessing risks of cancer and other health effects associated with long-term (chronic) exposures.

The toxic constituents of coke oven emissions include both gases (e.g., volatile organic chemicals such as benzene) and respirable particulate matter of varying chemical composition. The recommended approach for assessing risks from exposure to a mixture of pollutants, such as arising from coke ovens, is to utilize a dose-response assessment developed for that mixture (U.S.EPA 2000, U.S.EPA 1986a).
For assessment of inhalation cancer risks, a dose-response assessment is available for coke oven emissions as a mixture, and this was used for exposures arising from emissions from the battery (charging, door, lid and offtake leaks), and the pushing and quenching emissions points. Emissions from the pushing control device, combustion stack, and By-product plant were judged too dissimilar from the mixture on which the dose-response assessment is based. Consequently, for those emissions points, a component-by-component approach was employed. For assessment of inhalation non-cancer risks, as no dose-response assessment has been developed on a coke oven emissions mixture, the component -by-

component approach was employed for emissions from all emission points.

In this section, health effects information is summarized for "coke oven emissions", and individual constituents.

Coke Oven Emissions

Chronic (long-term) human exposure to coke oven emissions is associated with conjunctivitis, severe dermatitis, and lesions of the respiratory system and digestive system. Studies of coke oven workers have reported an increase in cancer of the lung, trachea, bronchus, kidney, prostate, and other sites. Animal studies have reported tumors of the lung and skin from inhalation and dermal exposure, respectively, to coal tar, a condensate from coke oven emissions (U.S.EPA 1984). EPA has classified coke oven emissions as Group A—a known human carcinogen (U.S.EPA 2003). The IRIS unit risk estimate was used in the inhalation cancer risk assessment.

Since the derivation of the IRIS unit risk estimate in 1984, additional health outcome data have been collected on the occupational cohort on which the dose-response assessment was based. A dose-response assessment using the updated data set (Moolgavkar et al 1998) yielded a slightly lower unit risk estimate. The upper confidence level value from that assessment is approximately 3.5 times lower than the corresponding IRIS URE. The Moolgavkar assessment, however, did not consider cancer deaths of cohort members past age 70, which is preferred in EPA cancer dose-response assessments where the epidemiological data will allow[10]. Such data are available and would need to be considered in re-calculating a unit risk estimate. It is presumed that making the adjustment for the available data past age 70 would result in a unit risk estimate value closer to the current IRIS value.

The surrogate measure for coke oven emissions used in the IRIS and Moolgavkar et al cancer dose-response assessment is benzene soluble organic material (BSO). In this risk assessment, for the emissions points identified above (i.e., battery charging, door, lid and offtake leaks, pushing and quenching), BSO, or where unavailable, MCSO (methylene chloride soluble organic material), was used as the surrogate measure of coke oven emissions.

Antimony

Human studies are inconclusive regarding antimony exposure and cancer, while animal studies have reported lung tumors in rats exposed to antimony trioxide via inhalation. EPA has not classified antimony for carcinogenicity, although the IARC has classified antimony trioxide as possibly carcinogenic to humans. Respiratory effects, such as inflammation of the lungs, chronic bronchitis, and chronic emphysema, are the primary effects noted from chronic (long-term) exposure to antimony in humans via

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[10] The Moolgavkar analysis considered lifetime cancer mortality in the cohort only up to 70 years. EPA usually goes up to 85 years or more if there data are available.

inhalation. Animal studies have reported a decrease in the number of offspring born to rats exposed to antimony prior to conception and throughout gestation. Reproductive effects, including metaplasia in the uterus and disturbances in the ovum-maturing process, were reported in a rat study, following inhalation exposure. The IRIS RfC for antimony trioxide based on pulmonary toxicity and chronic interstitial inflammation in rats was used in this assessment. This summary is based on IRIS (U.S.EPA, 2003) and the ATSDR Toxicological Profile for Antimony (ATSDR, 1992a).

Arsenic

Inorganic arsenic exposure in humans by the inhalation route has been shown to be strongly associated with lung cancer, while ingestion of inorganic arsenic in drinking water by humans has been linked to a form of skin cancer and also to bladder, liver, kidney, and lung cancer. EPA has classified inorganic arsenic as a group A, known human carcinogen. The EPA inhalation cancer unit risk estimate for inorganic arsenic was used in this assessment. Chronic (long-term) inhalation exposure to inorganic arsenic in humans is associated with irritation of the skin and mucous membranes, and neurological injury. Animal studies of inhalation exposure have indicated developmental effects. Chronic oral exposure has resulted in gastrointestinal effects, anemia, peripheral neuropathy, skin lesions, hyperpigmentation, and liver or kidney damage in humans. The inhalation reference value used for the assessment of noncancer effects is a California REL value based on findings of developmental toxicity in mice (CalEPA, 2000c). The EPA has not set an inhalation reference concentration for inorganic arsenic. This summary is based on IRIS (U.S.EPA 2003) and the ATSDR profile for arsenic (ATSDR, 2000a).

Benzene

The EPA has classified benzene as a Group A, known human carcinogen. Increased incidence of leukemia (cancer of the tissues that form white blood cells) has been observed in humans occupationally exposed to benzene. The EPA has derived a range of inhalation cancer unit risk estimates for benzene; the value at the high end of the range was used in this assessment. Chronic inhalation of certain levels of benzene causes disorders in the blood in humans. Benzene specifically affects bone marrow (the tissues that produce blood cells). Aplastic anemia,(1) excessive bleeding, and damage to the immune system (by changes in blood levels of antibodies and loss of white blood cells) may develop. In animals, chronic inhalation and oral exposure to benzene produces the same effects as seen in humans. Reproductive effects have been reported for women exposed by inhalation to high levels, and adverse effects on the developing fetus have been observed in animal tests. The inhalation reference value used for the assessment of noncancer effects is the IRIS RfC value of $3x10^{-2}$ mg/m^3, based on hematological effects in humans. Information used in this summary of benzene effects is based on IRIS (U.S.EPA 2003) and the ATSDR profile for benzene (1997a).

Beryllium

Human epidemiology studies are limited, but suggest a causal relationship between beryllium exposure and an increased risk of lung cancer. Inhalation exposure to beryllium has been demonstrated to cause lung cancer in rats and monkeys. EPA has classified beryllium as a Group B1, probable human carcinogen, and IARC has classified beryllium as carcinogenic to humans (group 1).

Chronic (long-term) inhalation exposure of humans to beryllium has been reported to cause chronic beryllium disease (berylliosis), in which granulomatous lesions (noncancerous) develop in the lung. Acute (short-term) inhalation exposure to high levels of beryllium has been observed to cause inflammation of the lungs or acute pneumonitis (reddening and swelling of the lungs) in humans; after exposure ends, these symptoms may be reversible. Inadequate information is available on the reproductive or developmental effects of beryllium in humans or animals following inhalation exposure. The RfC from IRIS, based on beryllium sensitization and progression to chronic beryllium disease was used in this assessment. This summary is based on IRIS support documents (U.S.EPA 1998) and the ATSDR Toxicological Profile for beryllium (ATSDR, 2002a).

1,3-Butadiene

Epidemiological studies of workers in rubber plants have shown an association between 1,3-butadiene exposure and increased incidence of leukemia. Animal studies have reported tumors at various sites from 1,3-butadiene exposure. EPA has classified 1,3-butadiene as a human carcinogen.

Epidemiological studies have reported a possible association between 1,3-butadiene exposure and cardiovascular diseases. A variety of reproductive and developmental effects have been observed in mice exposed to 1,3-butadiene by inhalation. There are no human data on reproductive or developmental effects. Few adverse noncancer effects other than reproductive and developmental effects have been observed in animal tests, except for hematological effects in mice exposed to higher concentrations. Acute (short-term) exposure to 1,3-butadiene by inhalation in humans results in irritation of the eyes, nasal passages, throat, and lungs. The RfC used for the assessment of noncancer effects is the U.S. EPA RfC based on ovarian atrophy in mice. This summary is based on IRIS (U.S.EPA, 2003).

Cadmium

An association between cadmium exposure and an increased risk of lung cancer has been reported from human studies, but these studies are inconclusive due to confounding factors. Animal studies have demonstrated an increase in lung cancer from long-term inhalation exposure to cadmium. The U.S. Environmental Protection Agency (EPA) has classified cadmium as a Group B1, probable human carcinogen. Chronic (long-term) inhalation or oral exposure to cadmium leads to a build-up of cadmium in the kidneys that can cause kidney disease. Cadmium has been shown to be a developmental toxicant in animals, resulting in fetal malformations and other effects, but no conclusive evidence exists in humans.

EPA has not established a RfC for cadmium. The “RfC” used for the assessment of noncancer effects is the California EPA REL based on kidney and respiratory effects in humans (CalEPA 2000). The acute (short-term) effects of cadmium in humans through inhalation exposure consist mainly of effects on the lung, such as pulmonary irritation. This summary is based on IRIS (U.S.EPA 2003), and the ATSDR Toxicological Profile for cadmium (ATSDR, 1999a).

Carbon disulfide

Acute (short-term) inhalation exposure of humans to carbon disulfide has caused changes in breathing and chest pains. Nausea, vomiting, dizziness, fatigue, headache, mood changes, lethargy, blurred vision, delirium, and convulsions have also been reported in humans acutely exposed by inhalation. Neurologic effects, including behavioral and neurophysiological changes, have been observed in chronic (long-term) human and animal inhalation studies. Reproductive effects, such as decreased sperm count and menstrual disturbances, have been observed in humans exposed to carbon disulfide by inhalation. Animal studies support these findings. EPA has not classified carbon disulfide for human carcinogenicity. The RfC for carbon disulfide is based on nervous system effects in humans. This summary is based on EPA’s Health and Environmental Effects Profile for Carbon disulfide (U.S.EPA 1986b) and the ATSDR Toxicological Profile for carbon disulfide (ATSDR, 1996).

Carbonyl sulfide

Limited information is available on the health effects of carbonyl sulfide. Acute (short-term) inhalation of high concentrations of carbonyl sulfide may cause narcotic effects in humans. Carbonyl sulfide may also irritate the eyes and skin in humans. No information is available on the chronic (long-term), reproductive, developmental, or carcinogenic effects of carbonyl sulfide in humans. EPA has not classified carbonyl sulfide with respect to potential carcinogenicity. This summary was based on IRIS (USPEA 2003) and the U.S. DHHS, Hazardous Substances Data Bank (2002).

Chromium

Chromium occurs in the environment primarily in two valence states, trivalent chromium (Cr III) and hexavalent chromium (Cr VI). Exposure may occur from natural or industrial sources of chromium.

The respiratory tract is the major target organ for chromium (VI) toxicity, for acute (short-term) and chronic (long-term) inhalation exposures. Human studies have clearly established that inhaled chromium (VI) is a human carcinogen, resulting in an increased risk of lung cancer. Animal studies have shown chromium (VI) to cause lung tumors via inhalation exposure. The U.S. Environmental Protection Agency (EPA) has classified chromium (VI) as a Group A, known human carcinogen. Other effects noted from chronic exposure include shortness of breath, coughing, and wheezing were reported from a case of acute exposure to chromium (VI), while perforations and ulcerations of the septum, bronchitis, decreased pulmonary function, pneumonia, and other respiratory effects. Limited human studies suggest that chromium (VI) inhalation exposure may be associated with complications during pregnancy and childbirth, while animal studies have not reported reproductive effects from inhalation exposure to chromium (VI).

Chromium III is much less toxic than chromium (VI). The respiratory tract is also the major target organ for chromium (III) toxicity, similar to chromium (VI). Chromium (III) is an essential element in humans, with a daily intake of 50 to 200 µg/d recommended for an adult. The body can detoxify some amount of chromium (VI) to chromium (III). This summary is based on ATSDR Toxicological Profile for chromium (ATSDR, 1998a) and support documents for IRIS (U.S.EPA, 1998b,c).

Cobalt

Acute (short-term) exposure to high levels of cobalt by inhalation in humans and animals results in respiratory effects, such as a significant decrease in ventilatory function, congestion, edema, and hemorrhage of the lung. Respiratory effects are also the major effects noted from chronic (long-term) exposure to cobalt by inhalation, with respiratory irritation, wheezing, asthma, pneumonia, and fibrosis noted. Cardiac effects, congestion of the liver, kidneys, and conjunctiva, and immunological effects have also been noted in chronically-exposed humans. Cobalt is an essential element in humans, as a constituent of vitamin B12. Human studies are inconclusive regarding inhalation exposure to cobalt and cancer, and the one available oral study did not report a correlation between cobalt in the drinking water and cancer deaths (ATSDR, 1992). EPA has not classified cobalt for carcinogenicity. EPA has not established a Reference Concentration (RfC) for cobalt. The “RfC” used in this assessment is the ATSDR MRL based on respiratory effects in rats and mice (ATSDR, 1992b).

Cresols, o- & p-

Acute (short-term) inhalation exposure by humans to mixed cresols results in respiratory tract irritation, with symptoms such as dryness, nasal constriction, and throat irritation. Mixed cresols are also strong dermal irritants. No information is available on the chronic (long-term) effects of mixed cresols in humans, while animal studies have reported effects on the blood, liver, kidney, and central nervous system (CNS), and reduced body weight, from oral and inhalation exposure to mixed cresols. Several animal studies suggest that o-cresol, m-cresol, and p-cresol may act as tumor promotors (ATSDR, 1990). EPA has classified o-cresol, m-cresol, and p-cresol as Group C, possible human carcinogens (U.S.EPA 2003). EPA has not established a Reference Concentration (RfC) for cresols. The “RfC” used in this assessment was the California Environmental Protection Agency a chronic reference exposure level based on nervous system effects in rats (CalEPA 2000c).

Cumene

Acute (short-term) inhalation exposure to cumene may cause headaches, dizziness, drowsiness, slight incoordination, and unconsciousness in humans. Cumene has a potent central nervous system (CNS) depressant action characterized by a slow induction period and long duration of narcotic effects in animals. Cumene is a skin and eye irritant. No information is available on the chronic (long-term), reproductive, developmental, or carcinogenic effects of cumene in humans. Animal studies have reported increased liver, kidney, and adrenal weights from inhalation exposure to cumene. The RfC for cumene is based on these effects in rats. EPA has classified cumene as a Group D, not classifiable as to human carcinogenicity. This summary is based on the IRIS file (U.S.EPA, 2003) and support document (U.S.EPA 1997).

Dibenzofuran

No information is available on the acute (short-term), chronic (long-term), reproductive, developmental, and carcinogenic effects of dibenzofuran in humans or animals. Health effects information is available on the polychlorinated dibenzofurans; however, the U.S. Environmental Protection Agency (EPA) has noted that the biological activity of various chlorinated dibenzofurans varies greatly, thus, risk assessment by analogy to any of these more widely studied compounds would not be recommended. EPA has classified dibenzofuran as a Group D, not classifiable as to human carcinogenicity (U.S.EPA, 1988; 2003). EPA has not established a Reference Concentration (RfC) for dibenzofuran.

Hydrochloric acid

Hydrochloric acid is corrosive to the eyes, skin, and mucous membranes. Acute (short-term) inhalation exposure may cause eye, nose, and respiratory tract irritation and inflammation and pulmonary edema in humans. Acute oral exposure may cause corrosion of the mucous membranes, esophagus, and stomach and dermal contact may produce severe burns, ulceration, and scarring in humans. Chronic (long-term) occupational exposure to hydrochloric acid has been reported to cause gastritis, chronic bronchitis, dermatitis, and photosensitization in workers. Prolonged exposure to low concentrations may also cause dental discoloration and erosion. In rats exposed to hydrochloric acid by inhalation, severe dyspnea, cyanosis, and altered estrus cycles have been reported in dams, and increased fetal mortality and decreased fetal weight have been reported in the offspring. The RfC for hydrochloric acid is based on hyperplasia of the nasal mucosa, larynx, and trachea in rats. EPA has not classified hydrochloric acid for carcinogenicity. This summary is based on the IRIS file (U.S.EPA, 2003) and HSDB (DHHS 1993).

Hydrogen cyanide

There is a paucity of studies on the carcinogenic effects of cyanide, via any route of exposure, in humans or animals. EPA has not classified cyanide for carcinogenicity. Chronic inhalation exposure to cyanide in humans results primarily in effects on the central nervous system (CNS), such as headaches, numbness, tremor, and loss of visual acuity. Other effects in humans include cardiovascular and respiratory effects, an enlarged thyroid gland, and irritation to the eyes and skin. Animal studies have reported effects on the nervous, cardiovascular, and respiratory systems. The RfC from IRIS based on CNS symptoms and thyroid effects in humans was used in this assessment. This summary is based on

IRIS (U.S.EPA, 2003) and the ATSDR profile for cyanide (ATSDR, 1993a).

Hydrofluoric acid

Acute (short-term) inhalation exposure to gaseous hydrogen fluoride can cause severe respiratory damage in humans, including severe irritation and pulmonary edema. Severe ocular irritation and dermal burns may occur following eye or skin exposure in humans. Chronic (long-term) exposure of humans to fluoride at low levels has a beneficial effect of dental cavity prevention and may also be useful for the treatment of osteoporosis. Exposure to higher levels of fluoride through drinking water may cause dental fluorosis or mottling, while very high exposures through drinking water or air can result in skeletal fluorosis in humans. The only developmental effect observed from fluoride exposure in humans is dental fluorosis which can occur in a child's teeth when a mother receives high levels of fluoride during pregnancy. EPA has not established a RfC for hydrogen fluoride. The “RfC” used in this assessment is a proposed California Environmental Protection Agency REL based on effects on bone density in humans (CalEPA, 1997). EPA has not classified hydrogen fluoride for carcinogenicity. This summary is based on the ASTDR profile (ATSDR, 1993b).

Lead

EPA has classified lead as a group B2, probable human carcinogen. Human studies are inconclusive regarding lead exposure and cancer, while animal studies have reported an increase in kidney cancer from lead exposure by the oral route. Long-term exposure to lead in humans results in effects on the blood, central nervous system (CNS), blood pressure, kidneys, and Vitamin D metabolism. Children are particularly sensitive to the chronic effects of lead, with slowed cognitive development, reduced growth and other effects reported. The Centers for Disease Control use blood lead concentration of 10 ug/dl in a child as the threshold for requiring monitoring and prevention activities (ATSDR 1999b). Irreversible neurological effects can be the result of lead exposure in early childhood. Animal studies have reported effects similar to those found in humans, with effects on the blood, kidneys, and nervous, immune, and cardiovascular systems noted. Reproductive effects, such as decreased sperm count in men and spontaneous abortions in women, have been associated with lead exposure. The developing fetus is at particular risk from maternal lead exposure, with low birth weight and slowed postnatal neuro-behavioral development noted. The inhalation value used in this assessment is the National Ambient Air Quality Standard (quarterly average) for lead. This summary is based on IRIS (U.S.EPA 2003) and the ATSDR profile for lead (ATSDR 1999b).

Manganese

The EPA has classified manganese as group D, not classifiable as to carcinogenicity in humans. No information is available about the cancer effects in humans from inhaling or ingesting manganese. Studies of animals ingesting high levels of manganese report mixed results, with several studies reporting no cancer effects and one study showing an increased in the occurrence of pancreatic tumors. Long term inhalation exposure of humans to high levels of manganese may result in a syndrome called manganism, characterized primarily by effects to the central nervous system. These effects typically begin with feelings of weakness and lethargy and progress to other symptoms such as speech disturbances, a mask-like face, tremors, and psychological disturbances. Other effects from inhaling manganese over a long period of time include increased incidence of cough and bronchitis and an increased susceptibility to infectious lung disease. Reproductive effects, such as impotence and loss of libido, have been noted in male workers afflicted with manganism attributed to occupational exposure to high levels of manganese by inhalation. Animal studies have reported degenerative changes in the seminiferous tubules leading to sterility from intratracheal instillation of high doses of manganese (experimentally delivering the manganese directly to the trachea). In young animals exposed to manganese orally, decreased testosterone production and retarded growth of the testes were reported. The RfC from IRIS, based on impairment of neuro-behavioral function in humans was used in this assessment. This summary is based on IRIS (U.S.EPA, 2003) and the ATSDR profile for manganese (ATSDR, 2000b).

Naphthalene

EPA has classified naphthalene as a Group C, possible human carcinogen. Additionally, using the 1996 Proposed Guidelines for Carcinogen Risk Assessment, the human carcinogenic potential of naphthalene via the oral or inhalation routes "cannot be determined" at this time based on human and animal data; however, there is suggestive evidence (observations of benign respiratory tumors and one carcinoma in female mice only exposed to naphthalene by inhalation. Additional support includes increase in respiratory tumors associated with exposure to 1-methyl naphthalene. Chronic exposure of workers and rodents to naphthalene has been reported to cause cataracts and damage to the retina. Diarrhea, lethargy, hunched posture, rough coats, decreased body weight, and lesions in the kidneys and thymus have been observed in rats and mice chronically exposed via gavage (experimentally placing the chemical in the stomach). Hemolytic anemia has been reported in infants born to mothers who "sniffed" and ingested naphthalene (as mothballs) during pregnancy. Naphthalene administered orally to animals caused no developmental effects, but maternal toxicity has been observed. In the inhalation risk assessment, the RfC from IRIS based on nasal effects in mice was used. This summary is based on IRIS (U.S.EPA, 2003) and the ATSDR profile for naphthalene (ATSDR, 1995a).

Nickel

Human studies have reported an increased risk of lung and nasal cancers among nickel refinery workers exposed to nickel refinery dust. Nickel refinery dust is a mixture of many nickel compounds, with nickel subsulfide being the major constituent. Animal studies have also reported lung tumors from inhalation exposure to nickel refinery dusts and to nickel subsulfide." EPA has classified nickel refinery dust and nickel subsulfide in Group A, Human Carcinogens. EPA has derived an inhalation cancer unit risk estimate for nickel refinery dust and nickel subsulfide. There is some uncertainty regarding the form of nickel present in air impacted by coke oven emissions. Recognizing this, nickel subsulfide was consider less relevant to the nickel associated with coke oven emissions than was nickel refinery dust.

The EPA inhalation unit risk estimate for nickel refinery dust was used in this inhalation assessment.

Chronic inhalation exposure to nickel in humans also results in respiratory effects, including a type of asthma specific to nickel, decreased lung function, and bronchitis. Animal studies have reported effect on the lungs and immune system from inhalation exposure to soluble and insoluble nickel compounds (nickel oxide, subsulfide, sulfate heptahydrate). Soluble nickel compounds are more toxic to the respiratory tract than less soluble compounds. No information is available regarding the reproductive or developmental effects of nickel in humans, but some animal studies have reported reproductive and developmental effects. The inhalation reference value used for the assessment of noncancer effects is an ATSDR MRL value based on findings of respiratory system effects reported in rats exposed to a soluble nickel salt The EPA has not set an inhalation reference concentration for any nickel compounds. This summary is based on IRIS (U.S.EPA 2003), the U.S.EPA Health Assessment Document for nickel (1986c) and the ATSDR profile for nickel (ATSDR, 1997b).

PAHs

The hazardous air pollutant term polycyclic organic matter defines a broad class of compounds that includes the PAH compounds, of which benzo[a]pyrene is a member. As described elsewhere in this document, PAHs emitted by coke ovens include: Acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(k)fluoranthene, chrysene, fluoranthene, and fluorene. The predominant sources of airborne benzo[a]pyrene (BaP) are combustion processes. Thus, this compound rarely enters the environment alone but rather is associated with additional PAHs and other components frequently present in both vapor phase and particulate form. Available epidemiological information, therefore, is from persons exposed to mixtures of PAHs, such as tobacco smoke, diesel exhaust, air pollutants, synthetic fuels, or other similar materials.

Human studies have reported an increase in lung cancer in humans exposed to POM-bearing mixtures including coke oven emissions, roofing tar emissions, and cigarette smoke. The types of cancer reported are often consistent with the exposure pathway: scrotal cancer and lung cancer in chimney sweeps exposed to soot; skin cancer (including scrotal cancer) where shale oils are used; and lung cancer where airborne exposure of PAHs occurs, such as in iron and steel foundries. Animal studies have reported respiratory tract tumors from inhalation exposure to benzo[a]pyrene and forestomach tumors, leukemia, and lung tumors from oral exposure to benzo[a]pyrene. EPA has classified seven PAHs (benzo[a]pyrene, benz[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3-cd]pyrene) as Group B2, probable human carcinogens. These substances have also been classified by the International Agency for Research on Cancer (IARC) as probably (2A) or possible (2B) carcinogenic to humans. Of the other coke oven constituents listed above, the following have been classified as not classifiable by EPA (D) or IARC (3): anthracene (D, 3), benzo(e)pyrene (3), fluoranthene (D, 3) and fluorene (D, 3). Acenaphthene and acenaphthylene have not been evaluated by either organization.

Skin exposures to mixtures of some PAHs cause skin disorders in humans and animals, and adverse skin effects have been noted in humans and animals following application of solutions containing benzo[a]pyrene. An epidemiological study of workers exposed by inhalation to the PAH, benzo[a]pyrene, and other particulate matter reported some respiratory effects. The role of benzo[a]pyrene in this association, however, is unclear. No information is available on the reproductive or developmental effects of POM in humans, but animal studies have reported that oral exposure to benzo[a]pyrene causes reproductive and developmental effects.

The UREs used for the seven PAHs in this assessment are from CalEPA based on a potency equivalency factor (PEF) approach. These relative activity values were developed by CalEPA and are referred to as PEFs (PEFs are analogous to the U.S. EPA's toxicity equivalency factor [TEF] scheme used for dioxins and furans). For air contaminants, relative potency to BaP based on data from inhalation studies is considered optimal. Otherwise, intrapulmonary or intratracheal administration is most relevant, because such studies are in the target organ of interest. The inhalation CalEPA URE based on respiratory tract tumors in hamsters and a linearized multistage procedure is used for inhalation cancer risk assessment for BaP (CalEPA, 1999). BaP was chosen as the primary representative of the class because of the large amount of toxicological data available on BaP (versus the relatively incomplete database for other PAHs), the availability of monitoring techniques for BaP, and the significant exposure expected (CalEPA, 1999). EPA has not established a Reference Concentration (RfC) or a Reference Dose (RfD) for POM or PAHs as a group or for any of the PAHs listed above. This summary is based on IRIS (U.S.EPA, 2003), the ATSDR profile for PAHs (ATSDR, 1995b), and California EPA documentation of their unit risk estimates (CalEPA, 1999).

Phenol

Phenol is highly irritating to the skin, eyes, and mucous membranes in humans after acute (short-term) inhalation or dermal exposures. Phenol is considered to be quite toxic to humans via oral exposure. Anorexia, progressive weight loss, diarrhea, vertigo, salivation, a dark coloration of the urine, and blood and liver effects have been reported in chronically (long-term) exposed humans. Animal studies have reported reduced fetal body weights, growth retardation, and abnormal development in the offspring of animals exposed to phenol by the oral route. EPA has not established a Reference Concentration (RfC) for phenol. The California EPA REL based on twitching, muscle tremors, and neurological impairment, as well as elevated serum liver enzymes in rats was used in this assessment. EPA has characterized phenol as Group D, not classifiable as to human carcinogenicity, under the 1986 Guidelines for Carcinogen Risk Assessment. Under the draft interim Guidelines (U.S. EPA, 1999), the data regarding the carcinogenicity of phenol via the oral, inhalation, and dermal exposure routes are considered inadequate for an assessment of human carcinogenic potential. This summary is based on the IRIS file and background document (U.S.EPA, 2003), and the ATSDR profile for phenol (ATSDR 1998b).

Phosphorus

While phosphorus, in the form of phosphate, is an essential nutrient, white phosphorus, which is used in the manufacture of munitions, pyrotechnics, explosives, smoke bombs, in artificial fertilizers, and rodenticides, is extremely toxic to humans when ingested. Ingestion of white phosphorus by humans causes gastrointestinal effects and severe effects on the kidneys, liver, cardiovascular system, and central nervous system (CNS). Inhalation exposure has resulted in respiratory tract irritation and coughing in humans. Chronic (long-term) exposure to white phosphorus in humans results in necrosis of the jaw, termed "phossy jaw." EPA has classified white phosphorus as a Group D, not classifiable as to human carcinogenicity (U.S.EPA, 2003). EPA has not established a Reference Concentration for white phosphorus. The “RfC” used in this assessment was the proposed California EPA REL for white phosphorus based on a reproductive toxicity in rats exposed orally (Cal-EPA, 1997).

Selenium

Selenium is a naturally occurring substance that is toxic at high concentrations but is also a nutritionally essential element. Hydrogen selenide is the most acutely toxic selenium compound. Acute (short-term) exposure to elemental selenium, hydrogen selenide, and selenium dioxide by inhalation results primarily in respiratory effects, such as irritation of the mucous membranes, pulmonary edema, severe bronchitis, and bronchial pneumonia. Epide miological studies of humans chronically (long-term) exposed to high levels of selenium in food and water have reported discoloration of the skin, pathological deformation and loss of nails, loss of hair, excessive tooth decay and discoloration, lack of mental alertness, and listlessness. The only selenium compound that has been shown to be carcinogenic in animals is selenium sulfide, which resulted in an increase in liver tumors from oral exposure. EPA has classified selenium sulfide as a Group B2, probable human carcinogen, and elemental selenium as a Group D, not classifiable as to human carcinogenicity (U.S.EPA, 2003). EPA has not established a Reference Concentration for selenium compounds. The “RfC” used in this assessment was the California EPA chronic reference exposure level based on clinical selenosis in humans (CalEPA, 2001).

Toluene

EPA has classified toluene as Group D, not classifiable as to human carcinogenicity. The central nervous system (CNS) is the primary target organ for toluene toxicity in both humans and animals. Chronic inhalation exposure of humans to toluene also causes irritation of the upper respiratory tract and eyes, sore throat, dizziness, and headache. Human studies have reported developmental effects, such as CNS dysfunction, attention deficits, and minor craniofacial and limb anomalies, in the children of pregnant women exposed to toluene or mixed solvents by inhalation. Reproductive effects, including an association between exposure to toluene and an increased incidence of spontaneous abortions, have also been noted. However, these studies are not conclusive due to many confounding variables. Animal studies have shown toluene to have developmental, but not reproductive, effects from inhalation exposure. The IRIS RfC for toluene, 0.4 mg/m^3, which was based on neurological effects in humans and degeneration of the nasal epithelium in rats, was used in this assessment. This summary is based on IRIS (U.S.EPA, 2003) and the ATSDR profile for toluene (ATSDR, 1994).

Xylenes (mixed isomers)

No information is available on the carcinogenic effects of mixed xylenes in humans, and animal studies have reported negative results from exposure via gavage (experimentally placing the chemical in the stomach). EPA has classified mixed xylenes as Group D, not classifiable as to human carcinogenicity. Chronic (long-term) inhalation exposure of humans to mixed xylenes results primarily in central nervous system (CNS) effects, such as headache, dizziness, fatigue, tremors, and incoordination. Respiratory, cardiovascular, and kidney effects have also been reported. Insufficient data are available on the developmental or reproductive effects of mixed xylenes in humans. Animal studies have reported developmental effects, such as an increased incidence of skeletal variations in fetuses and fetal resorptions via inhalation. The inhalation reference value used for the assessment of noncancer effects is an ATSDR MRL value based on based on neurological effects in occupationally exposed workers exposed to mixed xylenes. The EPA has not set an inhalation reference concentration for xylenes. This summary is based on IRIS (U.S.EPA, 2003) and the ATSDR profile for xylene (ATSDR, 1995c).

Table B-1. Chronic Inhalation Dose Response Values for Coke Oven Emissions Constituents

CAS #	Constituent	RfC mg/m3	RfC Source	URE $(\mu g/m3)^{-1}$	URE Source	Comment
83329	Acenaphthene					
208968	Acenaphthylene					
120127	Anthracene					
7440360	Antimony	0.0002	IRIS			RfC is for antimony trioxide
7440382	Arsenic	0.00003	CalEPA	$4.3x10^{-3}$	IRIS	
56553	Benz(a)anthracene			$1.1x10^{-4}$	CalEPA	
71432	Benzene	0.03	IRIS	$7.8x10^{-6}$	IRIS	
99992	Benzene soluble organics			$6.2x10^{-4}$	IRIS	URE is for coke oven emissions
50328	Benzo(a)pyrene			$1.1x10^{-3}$	CalEPA	
205992	Benzo(b)fluoranthene			$1.1x10^{-4}$	CalEPA	
192972	Benzo(e)pyrene					
207089	Benzo(k)fluoranthene			$1.1x10^{-4}$	CalEPA	
7440417	Beryllium	0.00002	IRIS	$2.4x10^{-3}$	IRIS	
106990	1,3-Butadiene	0.002	IRIS	$3.0x10^{-5}$	EPA	
7440439	Cadmium	0.00002	CalEPA	$1.8x10^{-3}$	IRIS	
75150	Carbon disulfide	0.7	IRIS			
463581	Carbonyl sulfide					
7440473	Chromium	0.0001	IRIS	$1.2x10^{-2}$	IRIS	RfC and URE are for chromium VI**
218019	Chrysene			$1.1x10^{-5}$	CalEPA	
7440484	Cobalt	0.0001	ATSDR			Value is draft MRL
95487	Cresol, o-	0.6	CalEPA			RfC is for cresols (mixed)
106445	Cresol, p-	0.6	CalEPA			RfC is for cresols (mixed)
98828	Cumene	0.4	IRIS			
132649	Dibenzofuran					
206440	Fluoranthene					
86737	Fluorene					
7647010	Hydrochloric acid (HCl)	0.02	IRIS			
74908	Hydrocyanic acid	0.003	IRIS			
7664393	Hydrofluoric acid (HF)	0.03	CalEPA-P			Proposed REL
193395	Indeno(1,2,3-cd) pyrene			$1.1x10^{-4}$	CalEPA	
7439921	Lead	$1.5x10^{-3}$	NAAQS*			Value is in ug/m^3
7439965	Manganese	0.00005	IRIS			
91576	Methylnaphthalene, 2-					
91203	Naphthalene	0.003	IRIS			
7440020	Nickel	0.0002	ATSDR	$2.4x10^{-4}$	IRIS	URE is for nickel refinery dust
85018	Phenanthrene					
108952	Phenol	0.2	CalEPA			
7723140	Phosphorus	0.00007	CalEPA-P			Proposed REL for white phosph.
129000	Pyrene					
7782492	Selenium	0.02	CalEPA			
108883	Toluene	0.4	IRIS			
1330207	Xylene (mixed isomers)	0.43	ATSDR			

* National Ambient Air Quality Standard (quarterly average)

** The atmosphere in the coking process is highly reducing. It is not likely the any Cr^{+6} (an oxidized state) would be present under such conditions.

Appendix B References

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Appendix C: Documentation of the Emission Estimates

Purpose and Approach

The purpose of this appendix is to document how the emissions were estimated for the coke ovens risk assessment. This section includes a description of the estimating procedures, example calculations, results for each battery and emission point, and references.

The approach for estimating emissions from the coking process (starting with charging coal to the oven and ending when the coke is quenched) is based on using extractable organic emissions as a surrogate for coke oven emissions. Data are available for benzene-soluble organics (BSO) and methylene-chloride-soluble organics (MCSO). Estimates for individual constituents in the coke oven emissions are derived from the ratio of the constituent to the BSO or MCSO. For the By-product recovery plants, benzene is the primary pollutant of concern. Estimates for the other HAPs, toluene and xylene, are based on their typical ratio to benzene.

Estimating Coke Oven Emissions by Process

BSO from Charging, Doors, Lids, and Offtakes

The estimates for charging, doors, lids, and offtakes are based on battery-specific data for the number of doors, lids, and offtakes on each battery and the number of charges per year. The battery characteristics are given in Table C-1 and were obtained from a U.S. Environmental Protection Agency (EPA) survey of the industry (Burns, 1998) and from an EPA report that assessed control performance for these emission points (U.S. EPA 1999c). Emission estimates are provided for three cases: one based on data from Method 303 inspections (actual visible emissions), summarized in Table C-2; one based on MACT1 emission limits given in Table C-3; and one based on 2010 LAER emission limits given in Table C-3. The Method 303 data were obtained from U.S. EPA (1999c) and supplemented by more recent data provided by two of the companies (Felton, 2001b; DeCamps 2001).

The estimating procedures are from the revised draft of AP-42 (U.S. EPA, 2001a). BSO emissions from door leaks are based on an emission rate of 0.04 lb/hr per leak for leaks visible from the yard (as determined by EPA Method 303[11]) and 0.023 lb/hr for leaks visible only from the bench

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[11] Method 303 specifies how emissions from the MACT 1 processes are to be monitored. Certified estimators observe each door during the coking process from a distance of between 50 and 100 feet and visually score the emissions. Estimates taken from this location are called "yard" estimates. When observations are made with the observer standing right next to the ovens, these are called "bench" estimates. Because the bench observations are made closer to the oven doors, the observer is more likely to see and record these emissions.

(estimated as 6 percent of the doors). The observations from the yard as specified in Method 303 determinations are made roughly 50 to 100 feet from the oven doors.

Table C-1. Site-Specific Battery Information

Plant	Battery ID	Number of Ovens	Number of Lids Per Oven	Number of Offtakes Per Oven	Cycle Time (Hrs)	Number of Doors	Number of Lids	Number of Offtakes	Charges Per Year
AK Steel, Ashland, KY	3	76	3	1	19	152	228	76	34,675
	4	70	4	2	18	140	280	140	33,692
AK Steel, Middletown, OH	3	76	3	2	20	152	228	152	34,142
Erie Coke, Erie, PA	A	23	4	1	28	46	92	23	7,196
	B	35	4	1	28	70	140	35	10,950
Tonawanda, Buffalo, NY	2	60	3	1	28	120	180	60	18,771

Table C-2. Method 303 Inspection Data

Plant	ID	Date		Method 303 Inspection Data Summary				
		From	To	Number	Avg s/chg	Avg PLD	Avg PLL	Avg PLO
AK Steel, Ashland, KY	3	01/01/96	04/30/01	1,948	3.74	2.43	0.130	0.82
	4	01/10/95	04/30/01	2,302	2.64	2.81	0.080	1.64
AK Steel, Middletown, OH	3	01/01/96	04/30/01	1,946	2.78	2.05	0.080	0.72
Erie Coke, Erie, PA	A	01/30/98	11/30/98	304	3.82	2.01	0.037	0.61
	B	01/30/98	11/30/98	304	3.82	1.58	0.056	0.87
Tonawanda, Buffalo, NY	2	08/29/97	11/30/98	430	2.35	2.49	0.033	0.33

s/chg = seconds per charge;
PLD = percent leaking doors;
PLL = percent leaking lids;
PLO = percent leaking offtakes.

Table C-3. 1993 MACT and 2010 LAER Emission Limits

PLANT	Battery ID	MACT Emission Limits				LAER Emission Limits			
		S/CHG	PLD	PLL	PLO	S/CHG	PLD	PLL	PLO
AK Steel, Ashland, KY	3	12	5.0	0.60	3.0	12	3.3	0.40	2.5
	4[1]	12	3.8	0.40	2.5	12	3.8	0.40	2.5
AK Steel, Middletown, OH	3	12	5.0	0.60	3.0	12	3.3	0.40	2.5
Erie Coke, Erie, PA	A	12	5.0	0.60	3.0	12	3.3	0.40	2.5
	B	12	5.0	0.60	3.0	12	3.3	0.40	2.5
Tonawanda, Buffalo, NY	2	12	5.0	0.60	3.00	12	3.3	0.40	2.5

[1] - Battery number 4 at the AK Steel, Ashland facility is subject to LAER emission limits.

s/chg = seconds per charge;
PLD = percent leaking doors;
PLL = percent leaking lids;
PLO = percent leaking offtakes.

EPA studies have found that when observations are made from the bench, just inches from the doors, more leaks are observed. One study found that an additional 6 percent of the doors were found to be leaking when observed from the bench (U.S. EPA, 1981). In addition, the coke oven National Emission Standard for Hazardous Air Pollutants (NESHAP) (40 CFR Part 63, Subpart L) allows 6 percent of the door leaks to be subtracted when they are observed from the bench under a cokeside shed to put them on a basis similar to Method 303 yard observations. Lid and offtake leaks are based on 0.0075 lb BSO/hr per leak as presented in the draft revisions to AP-42 (U.S. EPA, 2001a). Charging emissions are based on 0.0093 lb BSO for each 10 seconds of emissions (U.S. EPA, 2001a).

Emission estimates based on Method 303 are given in Table C-4, those based on maximum achievable control technology (MACT1) emission limits (i.e., allowable emissions) are given in Table C-5, and the LAER-based emission rates are shown in Table C-6. Example calculations are given below.

Example Calculation for AK–Ashland Battery 3 Based on Method 303 Data

Charging = (3.74 s/charge) × (34,675 charges/yr) × (0.0093 lb/10 seconds) = 121 lb/yr = 0.06 tpy BSO

Doors = (152 doors) × (2.43 percent leaking)/100 × (0.04 lb/hr) + (152 doors) × (6 percent leaking)/100 × (0.023 lb/hr) = 0.36 lb/hr = 1.6 tpy BSO

Lids = (228 lids) × (0.13 percent leaking)/100 × (0.0075 lb/hr) = 0.0022 lb/hr = 0.01 tpy BSO

Offtakes = (76 offtakes) × (0.82 percent leaking)/100 × (0.0075 lb/hr) = 0.0047 lb/hr = 0.02 tpy BSO

Table C-4. BSO Emission Estimates Based on Method 303

Plant	Battery ID	Tons per Year of BSO Based on Method 303 Inspections (Actual)				
		Doors	Lids	Offtakes	Charging	Total
AK Steel, Ashland, KY	3	1.57	0.010	0.020	0.060	1.66
	4	1.54	0.0074	0.075	0.041	1.66
AK Steel, Middletown, OH	3	1.46	0.0060	0.036	0.044	1.55
Erie Coke, Erie, PA	A	0.44	0.0011	0.0046	0.013	0.46
	B	0.62	0.0026	0.010	0.019	0.65
Tonawanda, Buffalo, NY	2	1.25	0.0020	0.0064	0.020	1.28

Table C-5. BSO Emission Estimates Based on MACT Emission Limits

Plant	Battery ID	Tons per Year of Benzene Soluble Organics (BSO) Based on Emission Limits (Allowables)				
		Doors	Lids	Offtakes	Charging	Total
AK Steel, Ashland, KY	3	2.25	0.045	0.07	0.19	2.56
	4	1.78	0.037	0.11	0.19	2.12
AK Steel, Middletown, OH	3	2.25	0.045	0.15	0.19	2.64
Erie Coke, Erie, PA	A	0.68	0.018	0.02	0.04	0.76
	B	1.04	0.028	0.03	0.06	1.16
Tonawanda, Buffalo, NY	2	1.78	0.035	0.06	0.10	1.98

Table C-6. BSO Emission Estimates Based on LAER Emission Limits

Plant	Battery ID	Tons per Year of BSO Based on LAER Emission Limits				
		Doors	Lids	Offtakes	Charging	Total
AK Steel, Ashland, KY	3	1.80	0.03	0.06	0.19	2.08
	4	1.78	0.04	0.11	0.19	2.12
AK Steel, Middletown, OH	3	1.80	0.03	0.12	0.19	2.14
Erie Coke, Erie, PA	A	0.60	0.01	0.02	0.04	0.67
	B	0.91	0.02	0.03	0.06	1.02
Tonawanda, Buffalo, NY	2	1.57	0.02	0.05	0.10	1.74

Emissions from Pushing, Quenching, and Combustion stacks

The procedure for estimating methylene chloride soluble organic (MCSO) emissions is described in *National Emission Standards for Hazardous Air Pollutants (NESHAP) for Coke Ovens: Pushing, Quenching, and Combustion Stacks–Background Information for Proposed Standards* (U.S. EPA, 2001b). The estimates from this document are based on the emissions expected after the standards for pushing, quenching, and combustion stacks are implemented. The estimates for pushing and combustion stacks are derived from two EPA tests, one at a battery producing foundry coke (U.S. EPA, 1999b) and one at a battery producing blast furnace coke (U.S. EPA, 1999a). Emissions from quench towers are based on a 1977 EPA test (U.S. EPA, 1979).

The emission factors are based on the tons of coke produced or the tons of coal charged. Site-specific information on tons of coal charged and tons of coke produced were obtained from an EPA survey (Burns, 1998) of the industry and from data compiled from a survey conducted by ICF Consulting (Paul, 2000).

Fugitive Pushing Emissions

Pushing emission occur frequently across a typical coke oven battery. For example, a battery with 76 ovens (e.g., the AK-Steel Ashland facility), would push coke approximately every 15 minutes. The duration of this push is short, approximately 1 minute per push. Given the frequency of pushing activities and the fact that pushing emissions dominate battery emissions, an assumption of continuous operations versus a batch or intermittent process, is a more appropriate way to characterize these emissions, especially for modeling purposes.

MCSO fugitive emissions from pushing are estimated as 0.0116 lb/ton coke produced for plants with control devices and 0.018 lb/ton coke produced for batteries without control devices. These emission factors are based on 0.5 percent of the pushes being severely green and a 10 percent capture efficiency, 5 percent of the pushes being moderately green and a 40 percent capture efficiency, and 94.5 percent of the pushes being nongreen and a 90 percent capture efficiency. The emission estimates for each battery are given in Table C-7, and an example calculation is given below.

Example Calculations for MCSO for AK Steel–Ashland Battery 3:

Pushing fugitives = 376,000 tpy coke × 0.0116 lb/ton = 4,400 lb/yr = 2.2 tpy MCSO

Table C-7. Emission Estimates for Fugitive Pushing

			MCSO (tpy)
Plant	**ID**	**Coke (tpy)**	**Pushing fugitives**
AK Steel, Ashland, KY	3	376,000	2.2
AK Steel, Ashland, KY	4	589,000	3.4
AK Steel, Middletown, OH	3	423,000	2.5
Erie Coke, Erie, PA	A	65,000	0.4
Erie Coke, Erie, PA	B	99,000	0.6
Tonawanda, Buffalo, NY	2	218,701	2.0

Emission factors for PAHs and metals for the ABC Coke test are given in Tables C-8 and C-9 respectively. The PAH results are based on the averages from Runs 2 and 3 and do not include Run 1. There was a severely green push during Run 1. The severely green push occurred from an oven that was adjacent to an oven that had been taken out of service for repair, which can cause inadequate coking on the side of the oven that shares flues with the empty oven. This push exhibited opacity that approached 100 percent, and the high opacity continued during travel to the quench tower. This is expected to be a rare occurrence after the MACT standard is in place because the proposed rule requires that actions be taken to mitigate the effect on adjacent ovens when an oven is taken out of service. In addition, the frequency of occurrence during Run 1 (1 in 21 pushes) is not representative of the performance of batteries on which MACT is based. The MACT batteries rarely have pushes that exceed an average opacity of 50 percent. Consequently, Run 1 at ABC Coke is not representative of emissions levels expected after the implementation of MACT.

The only data for benzene emissions from the control device were from a source test done at Bethlehem Steel, Burns Harbor, IN, 1995 (Mostardi-Platt, 1995a). Benzene results for three runs were $3.8\text{x}10^{-4}$, $2.5\text{x}10^{-4}$, and $9.9\text{ x}10^{-5}$ lbs /ton of coke. The average value of $2.4\text{x}10^{-4}$ lb/ton of coke was used to estimate benzene emissions from the control device.

Site-specific information on the tons of coke produced at each of the MACT track batteries was obtained from an EPA survey (Burns, 1998) of the industry and from data compiled from a survey conducted by ICF Consulting (Paul, 2000). The coke production in tons per year was multiplied by the emission factors (lb/ton of coke) to estimate the annual emissions in lbs/yr. These emission estimates are shown in Table C-10.

<u>An example calculation is given below for Battery 3 at AK Steel, Ashland, KY:</u>

Benzo(a)anthracene = 376,000 tpy coke × 3.7×10^{-7} lb/ton = 0.139 lb/yr
Arsenic = 376,000 tpy coke × 6.2×10^{-7} lb/ton = 0.233 lb/yr
Benzene = 376,000 tpy coke × 2.4×10^{-4} lb/ton = 91 lb/yr.

Table C-8. PAH Emission Factors for Pushing Control Device at ABC Coke

PAHs	Baghouse Outlet (lb/ton)		
	Run 2	Run 3	Average
Benzo(a)anthracene	3.7E-07	3.7E-07	3.7E-07
Benzo(a)pyrene	**ND**	**ND**	**ND**
Benzo(b)fluoranthene	2.8E-07	3.3E-07	3.1E-07
Benzo(k)fluoranthene	2.4E-07	2.2E-07	2.3E-07
Chrysene	9.8E-07	1.1E-06	1.0E-06
Dibenzo(a,h)anthracene	**ND**	**ND**	**ND**
Indeno(1,2,3-cd)pyrene	**ND**	**ND**	**ND**
Acenaphthene	3.8E-06	5.5E-06	4.7E-06
Acenaphthylene	3.4E-05	2.7E-05	3.1E-05
Anthracene	5.0E-06	8.0E-06	6.5E-06
Benzo(g,h,i)perylene	**ND**	**ND**	**ND**
Fluoranthene	5.0E-06	8.0E-06	6.5E-06
Fluorene	1.1E-05	1.4E-05	1.3E-05
Naphthalene	1.4E-04	1.7E-04	1.6E-04
Phenanthrene	6.9E-05	4.2E-05	5.6E-05
Pyrene	1.2E-05	1.0E-05	1.1E-05
2-Methylnaphthalene	3.7E-05	5.6E-05	4.7E-05
Benzo(e)pyrene	**ND**	1.7E-07	8.5E-08
Perylene	**ND**	**ND**	**ND**

ND = not detected

Table C-9. Metals Emission Factors for the Pushing Emission Control Device at ABC Coke

Metals	Baghouse Outlet (lb/ton)			
	Run 1	Run 2	Run 3	Average
Antimony	**ND**	**ND**	**ND**	**ND**
Arsenic	4.6E-7	5.7E-7	8.4E-7	6.2E-7
Barium	7.5E-6	9.9E-6	1.3E-5	1.0E-5
Beryllium	**ND**	4.3E-8	6.7E-8	3.7E-8
Cadmium	1.4E-7	1.7E-7	1.2E-7	1.4E-7
Chromium	2.9E-6	4.3E-6	5.9E-6	4.4E-6
Cobalt	**ND**	**ND**	**ND**	**ND**
Copper	4.3E-6	5.2E-6	7.4E-6	5.6E-6
Lead	1.8E-6	3.6E-6	2.7E-6	2.7E-6
Manganese	3.8E-6	6.5E-6	9.1E-6	6.4E-6
Nickel	**ND**	2.6E-6	2.0E-6	1.5E-6
Phosphorus	2.4E-5	2.2E-5	3.4E-5	2.7E-5
Selenium	**ND**	8.6E-7	**ND**	2.9E-7
Silver	**ND**	**ND**	**ND**	**ND**
Thallium	**ND**	**ND**	**ND**	**ND**
Zinc	1.7E-5	1.9E-5	2.5E-5	2.0E-5

ND = not detected

Table C-10. Emission Estimates for Pushing Emission Control Devices

Plant	**AK Steel, Ashland, KY**	**AK Steel, Ashland, KY**	**AK Steel, Middletown, OH**	**Erie Coke, Erie, PA**	**Erie Coke, Erie, PA**
Battery	**3**	**4**	**3**	**A**	**B**
Coke (tpy)	**376,000**	**589,000**	**423,000**	**65,000**	**99,000**
PAHs	**Emissions (lb/yr)**				
Benzo(a)anthracene	0.139	0.218	0.157	0.024	0.037
Benzo(b)fluoranthene	0.117	0.183	0.131	0.020	0.031
Benzo(k)fluoranthene	0.086	0.135	0.097	0.015	0.023
Chrysene	0.376	0.589	0.423	0.065	0.099
Acenaphthene	1.77	2.77	1.99	0.31	0.47
Acenaphthylene	11.7	18.3	13.1	2.0	3.1
Anthracene	2.44	3.83	2.75	0.42	0.64
Fluoranthene	2.44	3.83	2.75	0.42	0.64
Fluorene	4.89	7.66	5.50	0.85	1.29
Naphthalene	60	94	68	10	16
Phenanthrene	21	33	24	3.6	6
Pyrene	4.1	6.5	4.7	0.7	1.1
2-Methylnaphthalene	18	28	20	3.1	4.7
Benzo(e)pyrene	0.032	0.050	0.036	0.006	0.008
Metals					
Arsenic	0.233	0.365	0.262	0.040	0.061
Beryllium	0.014	0.022	0.016	0.002	0.004
Cadmium	0.053	0.082	0.059	0.009	0.014
Chromium	1.65	2.59	1.86	0.29	0.44
Lead	1.02	1.59	1.14	0.18	0.27
Manganese	2.41	3.77	2.71	0.42	0.63
Nickel	0.56	0.88	0.63	0.10	0.15
Phosphorus	10	16	11	1.8	2.7
Selenium	0.109	0.171	0.123	0.019	0.029
Benzene	91	143	103	16	24

Quenching Emissions

MCSO emissions from quenching are based on 0.00706 lb/ton of coal charged. Additional details are given in the *National Emission Standards for Hazardous Air Pollutants (NESHAP) for Coke Ovens: Pushing, Quenching, and Combustion Stacks–Background Information for Proposed Standards* (U.S. EPA, 2001b). Emission estimates are given in Table C-11, and an example calculation is given below.

Example Calculations for MCSO for AK Steel–Ashland Battery 3:

Quenching = 533,000 tpy coal × 0.00706 lb/ton = 3,800 lb/yr = 1.9 tpy MCSO

Combustion Stack Emissions

Emissions estimates for PAHs and metals from combustion stacks are also derived from the two EPA tests (U.S. EPA, 1999a, 1999b; Maret, 2001) and the ABC Coke results. The test results for ABC Coke are used because the battery condition (specifically the oven walls) is more representative of the MACT track batteries than the new battery at Burns Harbor would be. However, emissions are scaled based on opacity and volumetric flow rate as explained in the *Background Information Document for the MACT Standard* (U.S. EPA, 2001b). For example, the average opacity at ABC Coke was 1.7 percent, and the average opacity after MACT is implemented is estimated to be a maximum of 5 percent (the batteries used to establish the MACT standard for combustion stacks average 2 percent to 5 percent opacity). Consequently, emissions are scaled up by a factor of 2.9. In addition, the mass emission rate at a given concentration is proportional to the volumetric flow rate, which was 83,000 acfm at ABC Coke.

Emissions for a given battery are estimated from the lb/hr measured at ABC Coke from the following equation:

Emissions (lb/hr) = lb/hr (at ABC Coke) × 2.9 (opacity adjustment) × (acfm) / (83,000 acfm).

The test results for the PAHs and metals at ABC Coke are given in Tables C-12 and C-13, respectively. The annual emission estimates for PAHs and metals for the MACT track batteries are given in Table C-14.

An example calculation is given below for Battery 3 at AK Steel–Ashland:

Benzo(a)anthracene = 5.1×10^{-6} lb/hr × 2.9 × 54,200 acfm/83,000 acfm = 9.66×10^{-6} lb/hr = 0.085 lb/yr

Arsenic = 2.0×10^{-4} lb/hr × 2.9 × 54,200 acfm / 83,000 acfm = 3.79×10^{-4} lb/hr = 3.3 lb/yr.

The results of tests for benzene from combustion stacks at four batteries were reviewed to derive an emission factor. The test results are summarized in Table C-15. For this analysis, the test results in Table C-15 for Kaiser Steel and Bethlehem Steel were used. Benzene emissions from combustion stacks are based on a concentration of 3 ppm (6.07×10^{-7} lb/dscf) and the site-specific volumetric flow rate in dscfm. The emission estimates are given in Table C-16.

An example calculation is given below for Battery 3 at AK Steel–Ashland:

Benzene = 31,773 dscfm × 6.07×10^{-7} lb/dscf = 0.0193 lb/min = 10,100 lb/yr.

Table C-11. Emission Estimates for Quenching

Plant	Battery ID	Coal (tpy)	MCSO (tpy)
AK Steel, Ashland, KY	3	533,000	1.9
AK Steel, Ashland, KY	4	833,000	2.9
AK Steel, Middletown, OH	3	592,000	2.1
Erie Coke, Erie, PA	A	79,000	0.28
Erie Coke, Erie, PA	B	120,000	0.42
Tonawanda, Buffalo, NY	2	275,000	1.0

Table C-12. PAH Test Results for Combustion Stacks—ABC Coke

PAH	Emissions (lb/hr)				
	Run 1	Run 2	Run 3	Run 4	Average
Benzo(a)anthracene	8.6E-06	4.7E-06	**ND**	7.2E-06	5.1E-06
Benzo(a)pyrene	1.2E-05	9.9E-06	**ND**	7.7E-06	7.5E-06
Benzo(b)fluoranthene	1.5E-05	2.0E-05	1.1E-05	1.3E-05	1.4E-05
Benzo(k)fluoranthene	**ND**	1.2E-07	**ND**	1.4E-07	6.4E-08
Chrysene	2.0E-05	2.2E-05	1.5E-05	2.5E-05	2.0E-05
Dibenzo(a,h)anthracene	**ND**	**ND**	**ND**	**ND**	**ND**
Ideno(1,2,3-cd)pyrene	**ND**	**ND**	**ND**	**ND**	**ND**
Acenaphthene	1.5E-05	1.1E-05	6.0E-06	1.2E-05	1.1E-05
Acenaphthylene	8.6E-04	3.2E-03	6.5E-04	**ND**	1.2E-03
Anthracene	3.3E-07	4.1E-07	1.1E-05	3.6E-07	3.0E-06
Benzo(g,h,i)perylene	**ND**	**ND**	**ND**	**ND**	**ND**
Fluoranthene	2.9E-04	5.6E-04	2.4E-04	3.4E-04	3.6E-04
Fluorene	5.0E-05	3.2E-05	1.8E-05	6.3E-05	4.1E-05

Table C-12. PAH Test Results for Combustion Stacks—ABC Coke

PAH	Emissions (lb/hr)				
	Run 1	Run 2	Run 3	Run 4	Average
Naphthalene	5.3E-03	6.1E-03	3.8E-03	4.8E-03	5.0E-03
Phenanthrene	5.9E-04	9.4E-04	4.9E-04	8.5E-05	5.3E-04
Pyrene	1.5E-04	9.9E-04	1.7E-04	2.2E-04	3.8E-04
2-Methylnaphthalene	1.5E-04	1.1E-04	7.9E-05	2.1E-04	1.4E-04
Benzo(e)pyrene	1.6E-05	6.6E-05	1.8E-05	1.4E-05	2.8E-05
Perylene	**ND**	**ND**	**ND**	**ND**	**ND**

ND = not detected

Table C-13. Metals Test Results for Combustion Stacks—ABC Coke

Metal	Emissions (lb/hr)			
	Run 1	Run 2	Run 4	Average
Antimony	**ND**	**ND**	**ND**	**ND**
Arsenic	1.2E-4	2.4E-4	2.3E-4	2.0E-4
Barium	2.4E-4	5.7E-4	4.0E-4	4.1E-4
Beryllium	8.9E-7	3.3E-6	1.5E-6	1.9E-6
Cadmium	1.4E-5	1.7E-5	2.3E-5	1.8E-5
Chromium	2.3E-4	5.1E-4	2.8E-4	3.4E-4
Cobalt	**ND**	**ND**	**ND**	**ND**
Copper	2.2E-4	2.4E-4	2.8E-4	2.5E-4
Lead	3.6E-4	4.0E-4	2.6E-4	3.4E-4
Manganese	1.1E-4	2.7E-4	3.0E-4	2.2E-4
Nickel	4.9E-5	1.4E-4	7.8E-5	8.8E-5
Phosphorus	6.7E-4	1.7E-3	1.5E-3	1.3E-3
Selenium	8.9E-5	2.0E-4	2.5E-4	1.8E-4
Silver	**ND**	**ND**	**ND**	**ND**
Thallium	4.0E-5	4.8E-5	3.9E-5	4.2E-5
Zinc	1.2E-3	1.5E-3	1.5E-3	1.4E-3

ND = not detected

Table C-14. Emission Estimates of PAHS and Metals for Combustion Stacks

Plant	AK Steel, Ashland, KY	AK Steel, Ashland, KY	AK Steel, Middletown, OH	Erie Coke, Erie, PA	Tonawanda, Buffalo, NY
Stack	**9**	**15**	**1**	**1**	**2**
Battery	**3**	**4**	**W**	**A, B**	**2**
Stack gas flow rate (acfm)	**54,200**	**191,000**	**156,000**	**37,900**	**97,000**
PAHs	**EMISSIONS (lbs/yr)**				
Benzo(a)anthracene	0.085	0.298	0.244	0.059	0.151
Benzo(a)pyrene	0.124	0.438	0.358	0.087	0.223
Benzo(b)fluoranthene	0.232	0.818	0.668	0.162	0.416
Benzo(k)fluoranthene	0.0011	0.0037	0.0031	0.0007	0.0019
Chrysene	0.332	1.17	0.955	0.232	0.594
Acenaphthene	0.182	0.643	0.525	0.128	0.327
Acenaphthylene	19.9	70.2	57.3	13.9	35.6
Anthracene	0.050	0.175	0.143	0.035	0.089
Fluoranthene	6.0	21.0	17.2	4.2	10.7
Fluorene	0.680	2.40	1.96	0.476	1.22
Naphthalene	83	292	239	58	148
Phenanthrene	8.8	31.0	25.3	6.1	15.7
Pyrene	6.3	22.2	18.1	4.4	11.3
2-Methylnaphthalene	2.3	8.2	6.7	1.6	4.2
Benzo(e)pyrene	0.464	1.64	1.34	0.325	0.831
Metals					
Arsenic	3.3	11.7	9.5	2.3	5.9
Beryllium	0.032	0.111	0.091	0.022	0.056
Cadmium	0.299	1.05	0.859	0.209	0.534
Chromium	5.6	19.9	16.2	3.9	10.1
Lead	5.6	19.9	16.2	3.9	10.1
Manganese	3.6	12.9	10.5	2.6	6.5
Nickel	1.5	5.1	4.2	1.0	2.6
Phosphorus	21.6	76.0	62.1	15.1	38.6
Selenium	3.0	10.5	8.6	2.1	5.3

Table C-15. Test Results for Benzene from Combustion Stacks

Plant	Benzene Emissions from Combustion Stacks		
	ppm	lb/ton of coal	tons/yr
J&L Steel, Battery P-4, Pittsburgh, PA, May 1979[a]	0.6 to 1.6	0.0045 to 0.01	1.5 to 3.4
National Steel Battery C, Granite City, IL, July 1979[a]	0.1 to 0.2	0.0022 to 0.0031	0.3 to 0.4
Kaiser Steel Battery B, Fontana, CA, September 1979[a]	1.8 to 4.1	0.029 to 0.066	3.5 to 7.9
Bethlehem Steel Battery 1, Burns Harbor, IN, March 1995[b]	2.6 to 3.2	0.023 to 0.028	15 to 18

[a] U.S. EPA (1980)
[b] Mastardi-Platt (1995b)

Table C-16. Benzene Emission Estimates for Combustion Stacks

Plant	Stack	Battery	Stack gas flow rate (dscfm)	Benzene (lb/yr)
AK Steel, Ashland, KY	9	3	31,773	10,100
AK Steel, Ashland, KY	15	4	111,882	35,700
AK Steel, Middletown, OH	1	W	91,577	29,200
Erie Coke, Erie, PA	1	A, B	22,209	7,090
Tonawanda, Buffalo, NY	2	2	56,842	18,100

Benzene Emissions from Process Equipment in the By-Product Recovery Plant

Estimates of benzene emissions from process equipment in the by-product recovery plant are based on the emission factors in lb/ton of coke from AP-42 (U.S. EPA, 2001a) (see the excerpt provided in Attachment C-1 following the references). The emission factors are given in Table C-17—one set for furnace coke and one for foundry coke. Tonawanda and Erie Coke produce foundry coke, and the other plants produce furnace coke. Most of the emission factors are for sources with emissions controlled by gas blanketing as required by the benzene NESHAP for by-product recovery plants (40 CFR Part 61, Subpart L). The exceptions are the excess ammonia liquor tanks and light oil storage tanks for foundry coke batteries, which are not required to be controlled.

Table C-17. Benzene Emissions from Process Equipment in the By-Product Plant

			AK Steel, Ashland, KY	**AK Steel, Middletown, OH**	**Erie Coke, Erie, PA**	**Tonawanda, Buffalo, NY**
			tpy coke: 964,977	**tpy coke: 423,252**	**tpy coke: 164,123**	**tpy coke: 219,439**
	Benzene emission factor (lb/ton of coke produced)		**type of coke: furnace**	**type of coke: furnace**	**type of coke: foundry**	**type of coke: foundry**
Emission point	**furnace (lb/ton)**	**foundry (lb/ton)**	**Benzene emissions (lb/yr)**			
Light oil storage tank	0.00024	0.0062*	232	None	None	1361
Tar decanter	0.0022	0.001	2123	931	None	None
Tar sump	3.80E-04	1.80E-04	367	161	None	None
Tar dewatering	0.00084	0.0004	811	356	None	None
Tar storage tank	0.00076	0.00036	733	322	None	None
Light oil condenser	0.0036	0.0019	3474	None	None	None
Light oil sump	0.0006	0.00032	579	None	None	None
Flush liquor circulation tank	0.00052	0.00038	502	220	None	None
Excess ammonia liquor tank	0.000056	0.002*	54	24	328	439
Wash oil decanter	0.00015	0.000082	145	63	None	None
Wash oil tank	0.00015	0.000082	145	None	None	None
Ammonia still			None	None	None	2,800
Total Benzene Emissions (lbs/yr)			**9,163**	**2,076**	**328**	**4,600**

* Uncontrolled emission factor.

Site-specific information on the processes present at each plant is used to estimate emissions. For example, when emissions from processes are labeled as "None" in Table C-17, it means that the process is not present or that it is a closed vent system operated under negative pressure (no leaks). AK Steel–Middletown and Erie Coke do not have a light oil recovery process; consequently, they do not have a light oil condenser, light oil storage, and other process vessels associated with light oil recovery.

The estimate for the ammonia still for Tonawanda Coke was provided by the company. Erie Coke does not have an ammonia still and AK Steel vents it to a thermal oxidizer.

Example Calculation for AK Steel–Ashland:

Light oil storage = 964,977 tpy coke × 0.00024 lb/ton = 232 lb/yr

Emissions from Equipment Leaks

Benzene emissions from equipment leaks are estimated from the procedures in *Protocol for Equipment Leak Emission Estimates* (U.S. EPA, 1995). The protocol for estimating emissions is determined by the amount of information that is available. If there are no Method 21 data available, emissions are based on a single set of default emission factors. If there is information on the number of leaking components but no screening values from Method 21, the protocol applies one set of emission factors to nonleaking components and another set to leaking components. The most refined approach is based the actual screening value that is measured for a leaking component. Emissions are estimated for each leaking component, and a small default emission factor is applied to nonleaking components.

The plants with equipment in benzene service are those that recover light oil (a mixture of benzene, toluene, and xylene). AK Steel–Ashland and Tonawanda Coke have light oil recovery systems and equipment in benzene service. AK Steel–Ashland (Felton, 2001a) provided Method 21 data for inspections of their light oil system. Consequently, their emissions were estimated from correlations for the Method 21 screening values. Default emission factors from the protocol were applied to the equipment components for Tonawanda Coke. Each of the plants provided the number of equipment components (pumps, valves, flanges, pressure relief devices) in benzene service and the concentration of benzene in the process stream (Paul, 2000). Results are given in Table C-18 for AK Steel–Ashland and Table C-19 for Tonawanda Coke.

Example Calculation for AK Steel–Ashland:

- One valve leaking at a screening level of 5,000 ppm handling light oil (75 percent benzene) during one quarterly inspection (2,190 hr/yr):

  $2.29\text{E-}06 \times (5{,}000)^{0.746}$ = 0.0013 kg/hr × 2,190 hr/yr × 0.75 (fraction benzene) =
  2.2 kg/yr = 4.8 lb/yr

- One valve with screening level pegged at 10,000 ppm inspected annually:

  6.4E-2 kg/hr × 8,760 hr/yr × 0.75 (fraction benzene) = 420 kg/yr = 925 lb/yr

Example of Default Approach for Tonawanda Coke

- 36 valves handling light oil with 65 percent benzene—default emission factor is 0.0109 kg/hr per valve:

36 valves × 0.0109 kg/hr/valve × 0.65 (fraction benzene) × 2.2 lb/kg × 8,760 hr/yr = 4,916 lb/yr

Table C-18. Benzene Emissions from Equipment Leaks—AK Steel–Ashland

		Emissions from Leaking Components			
Component	**Percent Benzene**	**Screening Value (SV) ppmv**	**hrs/yr leaking**	**kg/hr**	**Benzene (lb/yr)**
Valve	75	5000	2190	2.29E-06×$(SV)^{0.746}$	4.8
Valve	75	10000	8760	6.40E-02	925
Pressure relief device	75	10000	4380	7.30E-02	528
Pressure relief device	75	10000	4380	7.30E-02	528
		Emissions from Nonleaking Components			
Stream	**Percent Benzene**	**Component**	**Number**	**Emission Factor (kg/hr/source)**	**Benzene (lb/yr)**
Light oil	75	Pump	5	2.40E-05	1.7
		Flange	46	3.10E-07	0.2
		Valve	91	7.80E-06	10.3
		Open end line	30	2.00E-06	0.9
Stream	**Percent Benzene**	**Component**	**Number**	**Emission Factor (kg/hr/source)**	**Benzene (lb/yr)**
Rich wash oil	3	Pump	3	1.14E-01	198
		Flange	10	2.50E-04	1
		Valve	116	1.09E-02	731
		Open end line	21	2.30E-03	28
Lean wash oil	0.14	Pump	3	1.14E-01	9
		Flange	10	2.50E-04	0.1
		Valve	131	1.09E-02	39
		Open end line	19	2.30E-03	1
		Total			**3,000**

Table C-19. Benzene Emissions from Equipment Leaks—Tonawanda Coke

Stream	% Benzene	Component	Number	Emission Factor (kg/hr/source)	Benzene (lb/yr)
Light oil	65	Pump	1	1.14E-01	1,428
		Flange	37	2.50E-04	116
		Valve	36	1.09E-02	4,916
		Open end line	1	2.30E-03	29
				Total	**6,500**

Benzene Emissions from Product Loading

Benzene emissions occur when tar and light oil are loaded into tank trucks. Emission estimates for product loading (based on AP-42 loading equations) were provided by AK Steel and Tonawanda Coke. AK Steel reported 5,600 lbs/yr of benzene emitted from loading light oil. Based on a coal usage rate of 1,305,000 tpy, the emission factor is 4.3E-3 lb/ton of coal. Tonawanda reported 840 lbs/yr, which gives an emission factor of 3.1E-3 lb/ton of coal based on coal usage of 275,000 tpy. The average of these emission factors (3.7E-3 lb/ton) was applied to the other plants to estimate emissions from loading light oil.

AK Steel reported 540 lbs/yr of benzene emissions from loading tar, which gives an emission factor of 4.1E-4 lb/ton of coal. In the absence of other information, this emission factor was applied to each of the other plants to estimate benzene emissions from tar loading. The results are summarized in Table C-20.

Benzene Emissions from Wastewater

Benzene emissions from wastewater were estimated from information provided by the plants on the quantity of benzene in wastewater and an estimate that 85 percent is emitted (from EPA (1998): *Locating and Estimating Air Emissions from Sources of Benzene*). Benzene emissions from wastewater are controlled because the benzene waste NESHAP (40 CFR Part 61, Subpart FF) applies to these plants. Results are given in Table C-20.

Table C-20. Benzene Emissions from Product Loading and Wastewater

Plant	Product	Benzene from loading (lb/yr)	Source	Benzene from wastewater (lb/yr)
AK–Ashland	Tar	540	AP-42[a]	900
	Light oil	5,600	AP-42[a]	
AK–Middletown	Tar	940	AP-42[a]	730
Tonawanda	Tar	120	Emission factor[b]	510
	Light oil	840	AP-42[a]	
Erie	Tar	120	Emission factor[b]	120

[a] From site-specific data and AP-42 procedures.

[b] From AK Steel (Ashland) emission factor of 4.1E-4 lb/ton coal charged.

Ratios of Other Constituents to Extractable Organics

Emission rates for constituents other than BSO were derived as ratios to BSO emissions. Data from 12 coke plants supplied by the American Coke and Coal Chemicals Institute (Ailor, 2000) indicate that EPA's group of seven PAHs comprise 4.5 percent of the BSO based on analyses of coal tar.

Data from other sources (as well as the results in Table C-21) indicate that benzo(a)pyrene, traditionally used as an indicator of coke oven emissions, is about 1 percent of the BSO (Mabey, 1977; Suta, 1978; White et al., N.d.). EPA conducted a source test in 1978 that measured BSO and PAHs in a lid leak during the first hour of coking (Hartman, 1978). The results for additional PAHs (other than the six PAHs listed in Table C-21) are given in Table C-22. Other constituents in coke oven emissions from the revised AP-42 (U.S. EPA, 2001a) are given in Table C-23.

Table C-21. Seven PAHs in BSO

7 PAHs	Average (%)	Range (%)
Benzo(a)anthracene	0.90	0.57 - 1.5
Benzo(a)pyrene	0.84	0.46 - 1.3
Benzo(b)fluoranthene	0.68	0.37 - 1.1
Benzo(k)fluoranthene	0.59	0.37 - 1.0
Chrysene	1.1	0.80 - 2.2
Ideno(1,2,3-cd)pyrene	0.37	0.21 - 0.53
Total	4.5	

Table C-22. Additional PAHs in BSO [a]

PAH	% of BSO
Fluoranthene	2.3
Fluorene	1.1
Naphthalene	10.5
Phenanthrene	4.2
Pyrene	2.4
Total	20.5

[a] From Hartman (1978)

Table C-23. Other Constituents in Coke Oven Emissions [a]

Compound	Ratio to BSO
Carbon monoxide	1.1
Carbon dioxide	0.5
Hydrogen sulfide	0.15
Ammonia	0.15
Hydrogen cyanide	0.05
Methane	2.7
Ethane	0.3
Propane	0.03
Butane	0.02
Ethylene	0.4
Propylene	0.08
Propyne	0.003
Butene	0.07
Pentene	0.01
Benzene	0.5
Toluene	0.04
Xylene	0.005
Acetylene	0.009
Butadiene	0.009
Carbonyl sulfide	0.001
Carbon disulfide	0.001
Thiophenes	0.003

Table C-23. (continued)

Table C-23. Other Constituents in Coke Oven Emissions [a]

Compound	Ratio to BSO
Ammonia and acids:	
HCl	0.0009
HF	5×10^{-6}
HNO_3	7×10^{-5}
H_2SO_4	0.0007
Metals:	
Arsenic	2×10^{-7}
Mercury	2×10^{-7}
Selenium	2×10^{-7}
Semivolatiles:	
Benzofuran	7×10^{-5}
Benzonitrile	2×10^{-5}
Dibenzofuran	9×10^{-6}
Dimethyl phenol	9×10^{-6}
Hexanoic acid dioctylester	2×10^{-5}
2-methyl phenol	7×10^{-5}
4-methyl phenol	2×10^{-4}
Phenol	6×10^{-4}
Propanenitrile	9×10^{-6}
Propynyl benzene	2×10^{-5}
Pyridine	0.0002
Trimethyl benzene	5×10^{-5}
Volatile organics:	
Methylethyl benzene	0.003

[a] From U.S. EPA (2001a)

For pushing emissions, data are available from EPA tests that quantified semivolatile organics and metals. The results are presented in Table C-24 for PAHs and Table C-25 for metals based on their ratio to MCSOs.

Table C-24. PAHs Identified in Fugitive Pushing Emissions [a]

6 PAHs	Ratio to MCSO
Benzo(a)anthracene	0.0017
Benzo(a)pyrene	0.0005
Benzo(b)fluoranthene	0.0015
Benzo(k)fluoranthene	0.0009
Chrysene	0.0029
Ideno(1,2,3-cd)pyrene	0.0010
Total 6 PAH	**.0084**
8 PAHs	**Ratio to MCSO**
Acenaphthene	0.0013
Acenaphthylene	0.0082
Anthracene	0.0015
Fluoranthene	0.0048
Fluorene	0.0019
Naphthalene	0.0330
Phenanthrene	0.0140
Pyrene	0.0033
Total 14 PAHs	**0.0770**
Other PAHs	**Ratio to MCSO**
2-Methylnaphthalene	0.0072
Benzo(e)pyrene	0.0006
Total -- all PAHs	**0.0840**

[a] **From U.S. EPA (1999b)**

Table C-25. Ratios of Metals to Extractable Organics for Fugitive Pushing Emissions

Metal	Ratio to Extractables Organics	
	ABC Coke[a]	Bethlehem[b]
Antimony	2.3E-05	4.7E-04
Arsenic	1.8E-03	1.0E-02
Beryllium	6.2E-05	1.3E-04
Cadmium	5.3E-04	2.4E-04
Chromium	1.6E-03	9.6E-04
Cobalt	2.9E-04	4.7E-04
Lead	2.6E-03	1.6E-02
Manganese	3.2E-03	5.1E-03
Mercury	**ND**	6.7E-05
Nickel	2.8E-03	9.8E-03
Selenium	5.9E-04	2.2E-03
Total	1.3E-02	4.6E-02

[a] From U.S.EPA 1999a
[b] From U.S.EPA 1999b

Ratio of Xylene and Toluene to Benzene in By-Product Recovery Plant Emissions

Data from several sources were examined and are listed below. The ratio of xylene to benzene ranges from 0.01 to 0.055, and the ratio of toluene to benzene ranges from 0.06 to 0.16.

- From *The Making, Shaping, and Treating of Steel* (United States Steel, 1985), composition of light oil (benzene, toluene, and xylene):

	%	Midrange %	Ratio to benzene
Benzene	60 - 85	72.5	
Toluene	6 - 17	11.5	0.16
Xylene	1 - 7	4	0.055

- From draft AP-42, Table 12.2.5 (U.S. EPA, 2001a), components of raw coke oven gas:

	Ratio to BSO	Ratio to benzene
Benzene	0.5	
Toluene	0.04	0.08
Xylene	0.005	0.01

- From *Identity and Chemical and Physical Properties of Compounds in Coke Oven Emissions– Minor Constituents in Coke Oven Gas* (Mabey, 1977):

	mg/m3	Ratio to benzene
Benzene	35,800	
	23,900	
	21,400	
Average	27,000	
Toluene	3,000	
	1,520	
Average	2,260	0.08
Xylene	500	0.02

- From *Identity and Chemical and Physical Properties of Compounds in Coke Oven Emissions—Selected Vapor Concentrations in the Coke Oven Battery Environment at Five U.S. Coke Plants* (Mabey, 1977):

	Mean mg/m3	Ratio to benzene
Benzene	9.5	
Toluene	0.6	0.06
Xylene	0.3	0.03

In this assessment, we chose these latter ratios, (i.e., 0.06 for toluene and 0.03 for xylene, from the Mabey study at 5 plants because these were derived from actual measurements of concentrations in the air around coke plants.

Emission Rates for Risk Modeling

The tables below provide the emission rates used for each facility by source and chemical. Tables C-26 through C-49 present process specific coke oven emissions estimated under MACT I. Tables C-50 through C-53 present MACT II emissions estimates and Tables C-54 through C-57 present by-product emission estimates. The key provides descriptions of acronyms used in the emission rates tables.

Key to Emission Rates Tables

Dispersion Sources:

BAT = Battery
BPP = By-Product Plan
COM = Combustion Stack
PCD = Pushing Control Device
QCT = Quenching

Units:

lb/yr = pounds per year
g/sec = grams per second

Table C-26 MACT I Emissions from Coke Battery- Battery doors at AK Steel Middletown

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$4.2\mathrm{x}10^{-2}$	$6.5\mathrm{x}10^{-2}$	$5.2\mathrm{x}10^{-2}$
50328	Benzo(a)pyrene	$3.5\mathrm{x}10^{-4}$	$5.4\mathrm{x}10^{-4}$	$4.3\mathrm{x}10^{-4}$
56553	Benzo(a)anthracene	$3.8\mathrm{x}10^{-4}$	$5.8\mathrm{x}10^{-4}$	$4.7\mathrm{x}10^{-4}$
71432	Benzene	$2.1\mathrm{x}10^{-2}$	$3.2\mathrm{x}10^{-2}$	$2.6\mathrm{x}10^{-2}$
74908	Hydrocyanic acid	$2.1\mathrm{x}10^{-3}$	$3.2\mathrm{x}10^{-3}$	$2.6\mathrm{x}10^{-3}$
75150	Carbon disulfide	$4.2\mathrm{x}10^{-5}$	$6.5\mathrm{x}10^{-5}$	$5.2\mathrm{x}10^{-5}$
85018	Phenanthrene	$1.8\mathrm{x}10^{-3}$	$2.7\mathrm{x}10^{-3}$	$2.2\mathrm{x}10^{-3}$
86737	Fluorene	$4.6\mathrm{x}10^{-4}$	$7.1\mathrm{x}10^{-4}$	$5.7\mathrm{x}10^{-4}$
91203	Naphthalene	$4.4\mathrm{x}10^{-3}$	$6.8\mathrm{x}10^{-3}$	$5.4\mathrm{x}10^{-3}$
95487	Cresol, o-	$2.9\mathrm{x}10^{-6}$	$4.5\mathrm{x}10^{-6}$	$3.6\mathrm{x}10^{-6}$
98828	Cumene	$1.3\mathrm{x}10^{-4}$	$1.9\mathrm{x}10^{-4}$	$1.6\mathrm{x}10^{-4}$
106445	Cresol, p-	$8.4\mathrm{x}10^{-6}$	$1.3\mathrm{x}10^{-5}$	$1.0\mathrm{x}10^{-5}$
106990	1,3-Butadiene	$3.8\mathrm{x}10^{-4}$	$5.8\mathrm{x}10^{-4}$	$4.7\mathrm{x}10^{-4}$
108883	Toluene	$1.7\mathrm{x}10^{-3}$	$2.6\mathrm{x}10^{-3}$	$2.1\mathrm{x}10^{-3}$
108952	Phenol	$2.5\mathrm{x}10^{-5}$	$3.9\mathrm{x}10^{-5}$	$3.1\mathrm{x}10^{-5}$
129000	Pyrene	$1.0\mathrm{x}10^{-3}$	$1.6\mathrm{x}10^{-3}$	$1.2\mathrm{x}10^{-3}$
132649	Dibenzofuran	$3.8\mathrm{x}10^{-7}$	$5.8\mathrm{x}10^{-7}$	$4.7\mathrm{x}10^{-7}$
193395	Indeno(1,2,3-cd)pyrene	$1.6\mathrm{x}10^{-4}$	$2.4\mathrm{x}10^{-4}$	$1.9\mathrm{x}10^{-4}$
205992	Benzo(b)fluoranthene	$2.9\mathrm{x}10^{-4}$	$4.4\mathrm{x}10^{-4}$	$3.5\mathrm{x}10^{-4}$
206440	Fluoranthene	$9.7\mathrm{x}10^{-4}$	$1.5\mathrm{x}10^{-3}$	$1.2\mathrm{x}10^{-3}$
207089	Benzo(k)fluoranthene	$2.5\mathrm{x}10^{-4}$	$3.8\mathrm{x}10^{-4}$	$3.1\mathrm{x}10^{-4}$
218019	Chrysene	$4.6\mathrm{x}10^{-4}$	$7.1\mathrm{x}10^{-4}$	$5.7\mathrm{x}10^{-4}$
463581	Carbonyl sulfide	$4.2\mathrm{x}10^{-5}$	$6.5\mathrm{x}10^{-5}$	$5.2\mathrm{x}10^{-5}$
1330207	Xylene (mixed isomers)	$2.1\mathrm{x}10^{-4}$	$3.2\mathrm{x}10^{-4}$	$2.6\mathrm{x}10^{-4}$
7440382	Arsenic	$8.4\mathrm{x}10^{-9}$	$1.3\mathrm{x}10^{-8}$	$1.0\mathrm{x}10^{-8}$
7647010	Hydrochloric acid	$3.8\mathrm{x}10^{-5}$	$5.8\mathrm{x}10^{-5}$	$4.7\mathrm{x}10^{-5}$
7664393	Hydrofluoric acid	$2.1\mathrm{x}10^{-7}$	$3.2\mathrm{x}10^{-7}$	$2.6\mathrm{x}10^{-7}$
7782492	Selenium	$8.4\mathrm{x}10^{-9}$	$1.3\mathrm{x}10^{-8}$	$1.0\mathrm{x}10^{-8}$

Table C-27 MACT I Emissions from Coke Battery- Battery lids at AK Steel Middletown

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$1.7x10^{-4}$	$1.3x10^{-3}$	$8.6x10^{-4}$
50328	Benzo(a)pyrene	$1.4x10^{-6}$	$1.1x10^{-5}$	$7.2x10^{-6}$
56553	Benzo(a)anthracene	$1.6x10^{-6}$	$1.2x10^{-5}$	$7.8x10^{-6}$
71432	Benzene	$8.6x10^{-5}$	$6.5x10^{-4}$	$4.3x10^{-4}$
74908	Hydrocyanic acid	$8.6x10^{-6}$	$6.5x10^{-5}$	$4.3x10^{-5}$
75150	Carbon disulfide	$1.7x10^{-7}$	$1.3x10^{-6}$	$8.6x10^{-7}$
85018	Phenanthrene	$7.2x10^{-6}$	$5.4x10^{-5}$	$3.6x10^{-5}$
86737	Fluorene	$1.9x10^{-6}$	$1.4x10^{-5}$	$9.5x10^{-6}$
91203	Naphthalene	$1.8x10^{-5}$	$1.4x10^{-4}$	$9.1x10^{-5}$
95487	Cresol, o-	$1.2x10^{-8}$	$9.1x10^{-8}$	$6.0x10^{-8}$
98828	Cumene	$5.2x10^{-7}$	$3.9x10^{-6}$	$2.6x10^{-6}$
106445	Cresol, p-	$3.5x10^{-8}$	$2.6x10^{-7}$	$1.7x10^{-7}$
106990	1,3-Butadiene	$1.6x10^{-6}$	$1.2x10^{-5}$	$7.8x10^{-6}$
108883	Toluene	$6.9x10^{-6}$	$5.2x10^{-5}$	$3.5x10^{-5}$
108952	Phenol	$1.0x10^{-7}$	$7.8x10^{-7}$	$5.2x10^{-7}$
129000	Pyrene	$4.1x10^{-6}$	$3.1x10^{-5}$	$2.1x10^{-5}$
132649	Dibenzofuran	$1.6x10^{-9}$	$1.2x10^{-8}$	$7.8x10^{-9}$
193395	Indeno(1,2,3-cd)pyrene	$6.4x10^{-7}$	$4.8x10^{-6}$	$3.2x10^{-6}$
205992	Benzo(b)fluoranthene	$1.2x10^{-6}$	$8.8x10^{-6}$	$5.9x10^{-6}$
206440	Fluoranthene	$4.0x10^{-6}$	$3.0x10^{-5}$	$2.0x10^{-5}$
207089	Benzo(k)fluoranthene	$1.0x10^{-6}$	$7.6x10^{-6}$	$5.1x10^{-6}$
218019	Chrysene	$1.9x10^{-6}$	$1.4x10^{-5}$	$9.5x10^{-6}$
463581	Carbonyl sulfide	$1.7x10^{-7}$	$1.3x10^{-6}$	$8.6x10^{-7}$
1330207	Xylene (mixed isomers)	$8.6x10^{-7}$	$6.5x10^{-6}$	$4.3x10^{-6}$
7440382	Arsenic	$3.5x10^{-11}$	$2.6x10^{-10}$	$1.7x10^{-10}$
7647010	Hydrochloric acid	$1.6x10^{-7}$	$1.2x10^{-6}$	$7.8x10^{-7}$
7664393	Hydrofluoric acid	$8.6x10^{-10}$	$6.5x10^{-9}$	$4.3x10^{-9}$
7782492	Selenium	$3.5x10^{-11}$	$2.6x10^{-10}$	$1.7x10^{-10}$

Table C-28 MACT I Emissions from Coke Battery - Battery Charging at AK Steel Middletown

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$1.3\mathrm{x}10^{-3}$	$5.5\mathrm{x}10^{-3}$	$5.5\mathrm{x}10^{-3}$
50328	Benzo(a)pyrene	$1.1\mathrm{x}10^{-5}$	$4.6\mathrm{x}10^{-5}$	$4.6\mathrm{x}10^{-5}$
56553	Benzo(a)anthracene	$1.1\mathrm{x}10^{-5}$	$4.9\mathrm{x}10^{-5}$	$4.9\mathrm{x}10^{-5}$
71432	Benzene	$6.3\mathrm{x}10^{-4}$	$2.7\mathrm{x}10^{-3}$	$2.7\mathrm{x}10^{-3}$
74908	Hydrocyanic acid	$6.3\mathrm{x}10^{-5}$	$2.7\mathrm{x}10^{-4}$	$2.7\mathrm{x}10^{-4}$
75150	Carbon disulfide	$1.3\mathrm{x}10^{-6}$	$5.5\mathrm{x}10^{-6}$	$5.5\mathrm{x}10^{-6}$
85018	Phenanthrene	$5.3\mathrm{x}10^{-5}$	$2.3\mathrm{x}10^{-4}$	$2.3\mathrm{x}10^{-4}$
86737	Fluorene	$1.4\mathrm{x}10^{-5}$	$6.0\mathrm{x}10^{-5}$	$6.0\mathrm{x}10^{-5}$
91203	Naphthalene	$1.3\mathrm{x}10^{-4}$	$5.7\mathrm{x}10^{-4}$	$5.7\mathrm{x}10^{-4}$
95487	Cresol, o-	$8.9\mathrm{x}10^{-8}$	$3.8\mathrm{x}10^{-7}$	$3.8\mathrm{x}10^{-7}$
98828	Cumene	$3.8\mathrm{x}10^{-6}$	$1.6\mathrm{x}10^{-5}$	$1.6\mathrm{x}10^{-5}$
106445	Cresol, p-	$2.5\mathrm{x}10^{-7}$	$1.1\mathrm{x}10^{-6}$	$1.1\mathrm{x}10^{-6}$
106990	1,3-Butadiene	$1.1\mathrm{x}10^{-5}$	$4.9\mathrm{x}10^{-5}$	$4.9\mathrm{x}10^{-5}$
108883	Toluene	$5.1\mathrm{x}10^{-5}$	$2.2\mathrm{x}10^{-4}$	$2.2\mathrm{x}10^{-4}$
108952	Phenol	$7.6\mathrm{x}10^{-7}$	$3.3\mathrm{x}10^{-6}$	$3.3\mathrm{x}10^{-6}$
129000	Pyrene	$3.0\mathrm{x}10^{-5}$	$1.3\mathrm{x}10^{-4}$	$1.3\mathrm{x}10^{-4}$
132649	Dibenzofuran	$1.1\mathrm{x}10^{-8}$	$4.9\mathrm{x}10^{-8}$	$4.9\mathrm{x}10^{-8}$
193395	Indeno(1,2,3-cd)pyrene	$4.7\mathrm{x}10^{-6}$	$2.0\mathrm{x}10^{-5}$	$2.0\mathrm{x}10^{-5}$
205992	Benzo(b)fluoranthene	$8.6\mathrm{x}10^{-6}$	$3.7\mathrm{x}10^{-5}$	$3.7\mathrm{x}10^{-5}$
206440	Fluoranthene	$2.9\mathrm{x}10^{-5}$	$1.3\mathrm{x}10^{-4}$	$1.3\mathrm{x}10^{-4}$
207089	Benzo(k)fluoranthene	$7.5\mathrm{x}10^{-6}$	$3.2\mathrm{x}10^{-5}$	$3.2\mathrm{x}10^{-5}$
218019	Chrysene	$1.4\mathrm{x}10^{-5}$	$6.0\mathrm{x}10^{-5}$	$6.0\mathrm{x}10^{-5}$
463581	Carbonyl sulfide	$1.3\mathrm{x}10^{-6}$	$5.5\mathrm{x}10^{-6}$	$5.5\mathrm{x}10^{-6}$
1330207	Xylene (mixed isomers)	$6.3\mathrm{x}10^{-6}$	$2.7\mathrm{x}10^{-5}$	$2.7\mathrm{x}10^{-5}$
7440382	Arsenic	$2.5\mathrm{x}10^{-10}$	$1.1\mathrm{x}10^{-9}$	$1.1\mathrm{x}10^{-9}$
7647010	Hydrochloric acid	$1.1\mathrm{x}10^{-6}$	$4.9\mathrm{x}10^{-6}$	$4.9\mathrm{x}10^{-6}$
7664393	Hydrofluoric acid	$6.3\mathrm{x}10^{-9}$	$2.7\mathrm{x}10^{-8}$	$2.7\mathrm{x}10^{-8}$
7782492	Selenium	$2.5\mathrm{x}10^{-10}$	$1.1\mathrm{x}10^{-9}$	$1.1\mathrm{x}10^{-9}$

Table C-29 MACT I Emissions from Coke Battery - Battery offtakes at AK Steel Middletown

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$1.0x10^{-3}$	$4.3x10^{-3}$	$3.5x10^{-3}$
50328	Benzo(a)pyrene	$8.7x10^{-6}$	$3.6x10^{-5}$	$2.9x10^{-5}$
56553	Benzo(a)anthracene	$9.3x10^{-6}$	$3.9x10^{-5}$	$3.1x10^{-5}$
71432	Benzene	$5.2x10^{-4}$	$2.2x10^{-3}$	$1.7x10^{-3}$
74908	Hydrocyanic acid	$5.2x10^{-5}$	$2.2x10^{-4}$	$1.7x10^{-4}$
75150	Carbon disulfide	$1.0x10^{-6}$	$4.3x10^{-6}$	$3.5x10^{-6}$
85018	Phenanthrene	$4.3x10^{-5}$	$1.8x10^{-4}$	$1.4x10^{-4}$
86737	Fluorene	$1.1x10^{-5}$	$4.7x10^{-5}$	$3.8x10^{-5}$
91203	Naphthalene	$1.1x10^{-4}$	$4.5x10^{-4}$	$3.6x10^{-4}$
95487	Cresol, o-	$7.2x10^{-8}$	$3.0x10^{-7}$	$2.4x10^{-7}$
98828	Cumene	$3.1x10^{-6}$	$1.3x10^{-5}$	$1.0x10^{-5}$
106445	Cresol, p-	$2.1x10^{-7}$	$8.6x10^{-7}$	$6.9x10^{-7}$
106990	1,3-Butadiene	$9.3x10^{-6}$	$3.9x10^{-5}$	$3.1x10^{-5}$
108883	Toluene	$4.1x10^{-5}$	$1.7x10^{-4}$	$1.4x10^{-4}$
108952	Phenol	$6.2x10^{-7}$	$2.6x10^{-6}$	$2.1x10^{-6}$
129000	Pyrene	$2.5x10^{-5}$	$1.0x10^{-4}$	$8.3x10^{-5}$
132649	Dibenzofuran	$9.3x10^{-9}$	$3.9x10^{-8}$	$3.1x10^{-8}$
193395	Indeno(1,2,3-cd)pyrene	$3.8x10^{-6}$	$1.6x10^{-5}$	$1.3x10^{-5}$
205992	Benzo(b)fluoranthene	$7.0x10^{-6}$	$2.9x10^{-5}$	$2.3x10^{-5}$
206440	Fluoranthene	$2.4x10^{-5}$	$9.9x10^{-5}$	$7.9x10^{-5}$
207089	Benzo(k)fluoranthene	$6.1x10^{-6}$	$2.5x10^{-5}$	$2.0x10^{-5}$
218019	Chrysene	$1.1x10^{-5}$	$4.7x10^{-5}$	$3.8x10^{-5}$
463581	Carbonyl sulfide	$1.0x10^{-6}$	$4.3x10^{-6}$	$3.5x10^{-6}$
1330207	Xylene (mixed isomers)	$5.2x10^{-6}$	$2.2x10^{-5}$	$1.7x10^{-5}$
7440382	Arsenic	$2.1x10^{-10}$	$8.6x10^{-10}$	$6.9x10^{-10}$
7647010	Hydrochloric acid	$9.3x10^{-7}$	$3.9x10^{-6}$	$3.1x10^{-6}$
7664393	Hydrofluoric acid	$5.2x10^{-9}$	$2.2x10^{-8}$	$1.7x10^{-8}$
7782492	Selenium	$2.1x10^{-10}$	$8.6x10^{-10}$	$6.9x10^{-10}$

Table C-30 MACT I Emissions from Coke Battery No.3 - Battery Charging at AK Steel Ashland

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$1.7x10^{-3}$	$5.5x10^{-3}$	$5.5x10^{-3}$
50328	Benzo(a)pyrene	$1.4x10^{-5}$	$4.6x10^{-5}$	$4.6x10^{-5}$
56553	Benzo(a)anthracene	$1.6x10^{-5}$	$4.9x10^{-5}$	$4.9x10^{-5}$
71432	Benzene	$8.6x10^{-4}$	$2.7x10^{-3}$	$2.7x10^{-3}$
74908	Hydrocyanic acid	$8.6x10^{-5}$	$2.7x10^{-4}$	$2.7x10^{-4}$
75150	Carbon disulfide	$1.7x10^{-6}$	$5.5x10^{-6}$	$5.5x10^{-6}$
85018	Phenanthrene	$7.2x10^{-5}$	$2.3x10^{-4}$	$2.3x10^{-4}$
86737	Fluorene	$1.9x10^{-5}$	$6.0x10^{-5}$	$6.0x10^{-5}$
91203	Naphthalene	$1.8x10^{-4}$	$5.7x10^{-4}$	$5.7x10^{-4}$
95487	Cresol, o-	$1.2x10^{-7}$	$3.8x10^{-7}$	$3.8x10^{-7}$
98828	Cumene	$5.2x10^{-6}$	$1.6x10^{-5}$	$1.6x10^{-5}$
106445	Cresol, p-	$3.5x10^{-7}$	$1.1x10^{-6}$	$1.1x10^{-6}$
106990	1,3-Butadiene	$1.6x10^{-5}$	$4.9x10^{-5}$	$4.9x10^{-5}$
108883	Toluene	$6.9x10^{-5}$	$2.2x10^{-4}$	$2.2x10^{-4}$
108952	Phenol	$1.0x10^{-6}$	$3.3x10^{-6}$	$3.3x10^{-6}$
129000	Pyrene	$4.1x10^{-5}$	$1.3x10^{-4}$	$1.3x10^{-4}$
132649	Dibenzofuran	$1.6x10^{-8}$	$4.9x10^{-8}$	$4.9x10^{-8}$
193395	Indeno(1,2,3-cd)pyrene	$6.4x10^{-6}$	$2.0x10^{-5}$	$2.0x10^{-5}$
205992	Benzo(b)fluoranthene	$1.2x10^{-5}$	$3.7x10^{-5}$	$3.7x10^{-5}$
206440	Fluoranthene	$4.0x10^{-5}$	$1.3x10^{-4}$	$1.3x10^{-4}$
207089	Benzo(k)fluoranthene	$1.0x10^{-5}$	$3.2x10^{-5}$	$3.2x10^{-5}$
218019	Chrysene	$1.9x10^{-5}$	$6.0x10^{-5}$	$6.0x10^{-5}$
463581	Carbonyl sulfide	$1.7x10^{-6}$	$5.5x10^{-6}$	$5.5x10^{-6}$
1330207	Xylene (mixed isomers)	$8.6x10^{-6}$	$2.7x10^{-5}$	$2.7x10^{-5}$
7440382	Arsenic	$3.5x10^{-10}$	$1.1x10^{-9}$	$1.1x10^{-9}$
7647010	Hydrochloric acid	$1.6x10^{-6}$	$4.9x10^{-6}$	$4.9x10^{-6}$
7664393	Hydrofluoric acid	$8.6x10^{-9}$	$2.7x10^{-8}$	$2.7x10^{-8}$
7782492	Selenium	$3.5x10^{-10}$	$1.1x10^{-9}$	$1.1x10^{-9}$

Table C-31 MACT I Emissions from Coke Battery No.3 - Battery doors at AK Steel Ashland

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$4.5\text{x}10^{-2}$	$6.5\text{x}10^{-2}$	$5.2\text{x}10^{-2}$
50328	Benzo(a)pyrene	$3.8\text{x}10^{-4}$	$5.4\text{x}10^{-4}$	$4.3\text{x}10^{-4}$
56553	Benzo(a)anthracene	$4.1\text{x}10^{-4}$	$5.8\text{x}10^{-4}$	$4.7\text{x}10^{-4}$
71432	Benzene	$2.3\text{x}10^{-2}$	$3.2\text{x}10^{-2}$	$2.6\text{x}10^{-2}$
74908	Hydrocyanic acid	$2.3\text{x}10^{-3}$	$3.2\text{x}10^{-3}$	$2.6\text{x}10^{-3}$
75150	Carbon disulfide	$4.5\text{x}10^{-5}$	$6.5\text{x}10^{-5}$	$5.2\text{x}10^{-5}$
85018	Phenanthrene	$1.9\text{x}10^{-3}$	$2.7\text{x}10^{-3}$	$2.2\text{x}10^{-3}$
86737	Fluorene	$5.0\text{x}10^{-4}$	$7.1\text{x}10^{-4}$	$5.7\text{x}10^{-4}$
91203	Naphthalene	$4.7\text{x}10^{-3}$	$6.8\text{x}10^{-3}$	$5.4\text{x}10^{-3}$
95487	Cresol, o-	$3.2\text{x}10^{-6}$	$4.5\text{x}10^{-6}$	$3.6\text{x}10^{-6}$
98828	Cumene	$1.4\text{x}10^{-4}$	$1.9\text{x}10^{-4}$	$1.6\text{x}10^{-4}$
106445	Cresol, p-	$9.0\text{x}10^{-6}$	$1.3\text{x}10^{-5}$	$1.0\text{x}10^{-5}$
106990	1,3-Butadiene	$4.1\text{x}10^{-4}$	$5.8\text{x}10^{-4}$	$4.7\text{x}10^{-4}$
108883	Toluene	$1.8\text{x}10^{-3}$	$2.6\text{x}10^{-3}$	$2.1\text{x}10^{-3}$
108952	Phenol	$2.7\text{x}10^{-5}$	$3.9\text{x}10^{-5}$	$3.1\text{x}10^{-5}$
129000	Pyrene	$1.1\text{x}10^{-3}$	$1.6\text{x}10^{-3}$	$1.2\text{x}10^{-3}$
132649	Dibenzofuran	$4.1\text{x}10^{-7}$	$5.8\text{x}10^{-7}$	$4.7\text{x}10^{-7}$
193395	Indeno(1,2,3-cd)pyrene	$1.7\text{x}10^{-4}$	$2.4\text{x}10^{-4}$	$1.9\text{x}10^{-4}$
205992	Benzo(b)fluoranthene	$3.1\text{x}10^{-4}$	$4.4\text{x}10^{-4}$	$3.5\text{x}10^{-4}$
206440	Fluoranthene	$1.0\text{x}10^{-3}$	$1.5\text{x}10^{-3}$	$1.2\text{x}10^{-3}$
207089	Benzo(k)fluoranthene	$2.7\text{x}10^{-4}$	$3.8\text{x}10^{-4}$	$3.1\text{x}10^{-4}$
218019	Chrysene	$5.0\text{x}10^{-4}$	$7.1\text{x}10^{-4}$	$5.7\text{x}10^{-4}$
463581	Carbonyl sulfide	$4.5\text{x}10^{-5}$	$6.5\text{x}10^{-5}$	$5.2\text{x}10^{-5}$
630080	Carbon monoxide	$5.0\text{x}10^{-2}$	$7.1\text{x}10^{-2}$	$5.7\text{x}10^{-2}$
1330207	Xylene (mixed isomers)	$2.3\text{x}10^{-4}$	$3.2\text{x}10^{-4}$	$2.6\text{x}10^{-4}$
7440382	Arsenic	$9.0\text{x}10^{-9}$	$1.3\text{x}10^{-8}$	$1.0\text{x}10^{-8}$
7647010	Hydrochloric acid	$4.1\text{x}10^{-5}$	$5.8\text{x}10^{-5}$	$4.7\text{x}10^{-5}$
7664393	Hydrofluoric acid	$2.3\text{x}10^{-7}$	$3.2\text{x}10^{-7}$	$2.6\text{x}10^{-7}$
7782492	Selenium	$9.0\text{x}10^{-9}$	$1.3\text{x}10^{-8}$	$1.0\text{x}10^{-8}$

Table C-32 MACT I Emissions from Coke Battery No.3 - Battery lids at AK Steel Ashland

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	2.9x10^{-4}	1.3x10^{-3}	8.6x10^{-4}
50328	Benzo(a)pyrene	2.4x10^{-6}	1.1x10^{-5}	7.2x10^{-6}
56553	Benzo(a)anthracene	2.6x10^{-6}	1.2x10^{-5}	7.8x10^{-6}
71432	Benzene	1.4x10^{-4}	6.5x10^{-4}	4.3x10^{-4}
74908	Hydrocyanic acid	1.4x10^{-5}	6.5x10^{-5}	4.3x10^{-5}
75150	Carbon disulfide	2.9x10^{-7}	1.3x10^{-6}	8.6x10^{-7}
85018	Phenanthrene	1.2x10^{-5}	5.4x10^{-5}	3.6x10^{-5}
86737	Fluorene	3.2x10^{-6}	1.4x10^{-5}	9.5x10^{-6}
91203	Naphthalene	3.0x10^{-5}	1.4x10^{-4}	9.1x10^{-5}
95487	Cresol, o-	2.0x10^{-8}	9.1x10^{-8}	6.0x10^{-8}
98828	Cumene	8.6x10^{-7}	3.9x10^{-6}	2.6x10^{-6}
106445	Cresol, p-	5.8x10^{-8}	2.6x10^{-7}	1.7x10^{-7}
106990	1,3-Butadiene	2.6x10^{-6}	1.2x10^{-5}	7.8x10^{-6}
108883	Toluene	1.2x10^{-5}	5.2x10^{-5}	3.5x10^{-5}
108952	Phenol	1.7x10^{-7}	7.8x10^{-7}	5.2x10^{-7}
129000	Pyrene	6.9x10^{-6}	3.1x10^{-5}	2.1x10^{-5}
132649	Dibenzofuran	2.6x10^{-9}	1.2x10^{-8}	7.8x10^{-9}
193395	Indeno(1,2,3-cd)pyrene	1.1x10^{-6}	4.8x10^{-6}	3.2x10^{-6}
205992	Benzo(b)fluoranthene	2.0x10^{-6}	8.8x10^{-6}	5.9x10^{-6}
206440	Fluoranthene	6.6x10^{-6}	3.0x10^{-5}	2.0x10^{-5}
207089	Benzo(k)fluoranthene	1.7x10^{-6}	7.6x10^{-6}	5.1x10^{-6}
218019	Chrysene	3.2x10^{-6}	1.4x10^{-5}	9.5x10^{-6}
463581	Carbonyl sulfide	2.9x10^{-7}	1.3x10^{-6}	8.6x10^{-7}
1330207	Xylene (mixed isomers)	1.4x10^{-6}	6.5x10^{-6}	4.3x10^{-6}
7440382	Arsenic	5.8x10^{-11}	2.6x10^{-10}	1.7x10^{-10}
7647010	Hydrochloric acid	2.6x10^{-7}	1.2x10^{-6}	7.8x10^{-7}
7664393	Hydrofluoric acid	1.4x10^{-9}	6.5x10^{-9}	4.3x10^{-9}
7782492	Selenium	5.8x10^{-11}	2.6x10^{-10}	1.7x10^{-10}

Table C-33 MACT I Emissions from Coke Battery No.3 - Battery offtakes at AK Steel Ashland

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$5.8x10^{-4}$	$2.0x10^{-3}$	$1.7x10^{-3}$
50328	Benzo(a)pyrene	$4.8x10^{-6}$	$1.7x10^{-5}$	$1.4x10^{-5}$
56553	Benzo(a)anthracene	$5.2x10^{-6}$	$1.8x10^{-5}$	$1.6x10^{-5}$
71432	Benzene	$2.9x10^{-4}$	$1.0x10^{-3}$	$8.6x10^{-4}$
74908	Hydrocyanic acid	$2.9x10^{-5}$	$1.0x10^{-4}$	$8.6x10^{-5}$
75150	Carbon disulfide	$5.8x10^{-7}$	$2.0x10^{-6}$	$1.7x10^{-6}$
85018	Phenanthrene	$2.4x10^{-5}$	$8.5x10^{-5}$	$7.2x10^{-5}$
86737	Fluorene	$6.3x10^{-6}$	$2.2x10^{-5}$	$1.9x10^{-5}$
91203	Naphthalene	$6.0x10^{-5}$	$2.1x10^{-4}$	$1.8x10^{-4}$
95487	Cresol, o-	$4.0x10^{-8}$	$1.4x10^{-7}$	$1.2x10^{-7}$
98828	Cumene	$1.7x10^{-6}$	$6.0x10^{-6}$	$5.2x10^{-6}$
106445	Cresol, p-	$1.2x10^{-7}$	$4.0x10^{-7}$	$3.5x10^{-7}$
106990	1,3-Butadiene	$5.2x10^{-6}$	$1.8x10^{-5}$	$1.6x10^{-5}$
108883	Toluene	$2.3x10^{-5}$	$8.1x10^{-5}$	$6.9x10^{-5}$
108952	Phenol	$3.5x10^{-7}$	$1.2x10^{-6}$	$1.0x10^{-6}$
129000	Pyrene	$1.4x10^{-5}$	$4.8x10^{-5}$	$4.1x10^{-5}$
132649	Dibenzofuran	$5.2x10^{-9}$	$1.8x10^{-8}$	$1.6x10^{-8}$
193395	Indeno(1,2,3-cd)pyrene	$2.1x10^{-6}$	$7.5x10^{-6}$	$6.4x10^{-6}$
205992	Benzo(b)fluoranthene	$3.9x10^{-6}$	$1.4x10^{-5}$	$1.2x10^{-5}$
206440	Fluoranthene	$1.3x10^{-5}$	$4.6x10^{-5}$	$4.0x10^{-5}$
207089	Benzo(k)fluoranthene	$3.4x10^{-6}$	$1.2x10^{-5}$	$1.0x10^{-5}$
218019	Chrysene	$6.3x10^{-6}$	$2.2x10^{-5}$	$1.9x10^{-5}$
463581	Carbonyl sulfide	$5.8x10^{-7}$	$2.0x10^{-6}$	$1.7x10^{-6}$
1330207	Xylene (mixed isomers)	$2.9x10^{-6}$	$1.0x10^{-5}$	$8.6x10^{-6}$
7440382	Arsenic	$1.2x10^{-10}$	$4.0x10^{-10}$	$3.5x10^{-10}$
7647010	Hydrochloric acid	$5.2x10^{-7}$	$1.8x10^{-6}$	$1.6x10^{-6}$
7664393	Hydrofluoric acid	$2.9x10^{-9}$	$1.0x10^{-8}$	$8.6x10^{-9}$
7782492	Selenium	$1.2x10^{-10}$	$4.0x10^{-10}$	$3.5x10^{-10}$

Table C-34 MACT I Emissions from Coke Battery No. 4 - Battery Charging at AK Steel Ashland

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$1.2x10^{-3}$	$5.5x10^{-3}$	$5.5x10^{-3}$
50328	Benzo(a)pyrene	$9.7x10^{-6}$	$4.6x10^{-5}$	$4.6x10^{-5}$
56553	Benzo(a)anthracene	$1.0x10^{-5}$	$4.9x10^{-5}$	$4.9x10^{-5}$
71432	Benzene	$5.8x10^{-4}$	$2.7x10^{-3}$	$2.7x10^{-3}$
74908	Hydrocyanic acid	$5.8x10^{-5}$	$2.7x10^{-4}$	$2.7x10^{-4}$
75150	Carbon disulfide	$1.2x10^{-6}$	$5.5x10^{-6}$	$5.5x10^{-6}$
85018	Phenanthrene	$4.8x10^{-5}$	$2.3x10^{-4}$	$2.3x10^{-4}$
86737	Fluorene	$1.3x10^{-5}$	$6.0x10^{-5}$	$6.0x10^{-5}$
91203	Naphthalene	$1.2x10^{-4}$	$5.7x10^{-4}$	$5.7x10^{-4}$
95487	Cresol, o-	$8.1x10^{-8}$	$3.8x10^{-7}$	$3.8x10^{-7}$
98828	Cumene	$3.5x10^{-6}$	$1.6x10^{-5}$	$1.6x10^{-5}$
106445	Cresol, p-	$2.3x10^{-7}$	$1.1x10^{-6}$	$1.1x10^{-6}$
106990	1,3-Butadiene	$1.0x10^{-5}$	$4.9x10^{-5}$	$4.9x10^{-5}$
108883	Toluene	$4.6x10^{-5}$	$2.2x10^{-4}$	$2.2x10^{-4}$
108952	Phenol	$6.9x10^{-7}$	$3.3x10^{-6}$	$3.3x10^{-6}$
129000	Pyrene	$2.8x10^{-5}$	$1.3x10^{-4}$	$1.3x10^{-4}$
132649	Dibenzofuran	$1.0x10^{-8}$	$4.9x10^{-8}$	$4.9x10^{-8}$
193395	Indeno(1,2,3-cd)pyrene	$4.3x10^{-6}$	$2.0x10^{-5}$	$2.0x10^{-5}$
205992	Benzo(b)fluoranthene	$7.8x10^{-6}$	$3.7x10^{-5}$	$3.7x10^{-5}$
206440	Fluoranthene	$2.6x10^{-5}$	$1.3x10^{-4}$	$1.3x10^{-4}$
207089	Benzo(k)fluoranthene	$6.8x10^{-6}$	$3.2x10^{-5}$	$3.2x10^{-5}$
218019	Chrysene	$1.3x10^{-5}$	$6.0x10^{-5}$	$6.0x10^{-5}$
463581	Carbonyl sulfide	$1.2x10^{-6}$	$5.5x10^{-6}$	$5.5x10^{-6}$
1330207	Xylene (mixed isomers)	$5.8x10^{-6}$	$2.7x10^{-5}$	$2.7x10^{-5}$
7440382	Arsenic	$2.3x10^{-10}$	$1.1x10^{-9}$	$1.1x10^{-9}$
7647010	Hydrochloric acid	$1.0x10^{-6}$	$4.9x10^{-6}$	$4.9x10^{-6}$
7664393	Hydrofluoric acid	$5.8x10^{-9}$	$2.7x10^{-8}$	$2.7x10^{-8}$
7782492	Selenium	$2.3x10^{-10}$	$1.1x10^{-9}$	$1.1x10^{-9}$

Table C-35 MACT I Emissions from Coke Battery No. 4 - Battery doors at AK Steel Ashland

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT[1]	LAER
99992	Benzene soluble organics	$4.4x10^{-2}$	$5.1x10^{-2}$	$5.1x10^{-2}$
50328	Benzo(a)pyrene	$3.7x10^{-4}$	$4.3x10^{-4}$	$4.3x10^{-4}$
56553	Benzo(a)anthracene	$4.0x10^{-4}$	$4.6x10^{-4}$	$4.6x10^{-4}$
71432	Benzene	$2.2x10^{-2}$	$2.6x10^{-2}$	$2.6x10^{-2}$
74908	Hydrocyanic acid	$2.2x10^{-3}$	$2.6x10^{-3}$	$2.6x10^{-3}$
75150	Carbon disulfide	$4.4x10^{-5}$	$5.1x10^{-5}$	$5.1x10^{-5}$
85018	Phenanthrene	$1.9x10^{-3}$	$2.2x10^{-3}$	$2.2x10^{-3}$
86737	Fluorene	$4.9x10^{-4}$	$5.6x10^{-4}$	$5.6x10^{-4}$
91203	Naphthalene	$4.7x10^{-3}$	$5.4x10^{-3}$	$5.4x10^{-3}$
95487	Cresol, o-	$3.1x10^{-6}$	$3.6x10^{-6}$	$3.6x10^{-6}$
98828	Cumene	$1.3x10^{-4}$	$1.5x10^{-4}$	$1.5x10^{-4}$
106445	Cresol, p-	$8.9x10^{-6}$	$1.0x10^{-5}$	$1.0x10^{-5}$
106990	1,3-Butadiene	$4.0x10^{-4}$	$4.6x10^{-4}$	$4.6x10^{-4}$
108883	Toluene	$1.8x10^{-3}$	$2.0x10^{-3}$	$2.0x10^{-3}$
108952	Phenol	$2.7x10^{-5}$	$3.1x10^{-5}$	$3.1x10^{-5}$
129000	Pyrene	$1.1x10^{-3}$	$1.2x10^{-3}$	$1.2x10^{-3}$
132649	Dibenzofuran	$4.0x10^{-7}$	$4.6x10^{-7}$	$4.6x10^{-7}$
193395	Indeno(1,2,3-cd)pyrene	$1.6x10^{-4}$	$1.9x10^{-4}$	$1.9x10^{-4}$
205992	Benzo(b)fluoranthene	$3.0x10^{-4}$	$3.5x10^{-4}$	$3.5x10^{-4}$
206440	Fluoranthene	$1.0x10^{-3}$	$1.2x10^{-3}$	$1.2x10^{-3}$
207089	Benzo(k)fluoranthene	$2.6x10^{-4}$	$3.0x10^{-4}$	$3.0x10^{-4}$
218019	Chrysene	$4.9x10^{-4}$	$5.6x10^{-4}$	$5.6x10^{-4}$
463581	Carbonyl sulfide	$4.4x10^{-5}$	$5.1x10^{-5}$	$5.1x10^{-5}$
1330207	Xylene (mixed isomers)	$2.2x10^{-4}$	$2.6x10^{-4}$	$2.6x10^{-4}$
7440382	Arsenic	$8.9x10^{-9}$	$1.0x10^{-8}$	$1.0x10^{-8}$
7647010	Hydrochloric acid	$4.0x10^{-5}$	$4.6x10^{-5}$	$4.6x10^{-5}$
7664393	Hydrofluoric acid	$2.2x10^{-7}$	$2.6x10^{-7}$	$2.6x10^{-7}$
7782492	Selenium	$8.9x10^{-9}$	$1.0x10^{-8}$	$1.0x10^{-8}$

[1] Battery No. 4 is operating at LAER emission limits

Table C-36 MACT I Emissions from Coke Battery No. 4 - Battery lids at AK Steel Ashland

CAS #	Constituent	Emission Rate (g/s		
		Actual	MACT	LAER
99992	Benzene soluble organics	$2.0x10^{-4}$	$1.1x10^{-3}$	$1.2x10^{-3}$
50328	Benzo(a)pyrene	$1.7x10^{-6}$	$8.9x10^{-6}$	$9.7x10^{-6}$
56553	Benzo(a)anthracene	$1.8x10^{-6}$	$9.6x10^{-6}$	$1.0x10^{-5}$
71432	Benzene	$1.0x10^{-4}$	$5.3x10^{-4}$	$5.8x10^{-4}$
74908	Hydrocyanic acid	$1.0x10^{-5}$	$5.3x10^{-5}$	$5.8x10^{-5}$
75150	Carbon disulfide	$2.0x10^{-7}$	$1.1x10^{-6}$	$1.2x10^{-6}$
85018	Phenanthrene	$8.5x10^{-6}$	$4.5x10^{-5}$	$4.8x10^{-5}$
86737	Fluorene	$2.2x10^{-6}$	$1.2x10^{-5}$	$1.3x10^{-5}$
91203	Naphthalene	$2.1x10^{-5}$	$1.1x10^{-4}$	$1.2x10^{-4}$
95487	Cresol, o-	$1.4x10^{-8}$	$7.5x10^{-8}$	$8.1x10^{-8}$
98828	Cumene	$6.0x10^{-7}$	$3.2x10^{-6}$	$3.5x10^{-6}$
106445	Cresol, p-	$4.0x10^{-8}$	$2.1x10^{-7}$	$2.3x10^{-7}$
106990	1,3-Butadiene	$1.8x10^{-6}$	$9.6x10^{-6}$	$1.0x10^{-5}$
108883	Toluene	$8.1x10^{-6}$	$4.3x10^{-5}$	$4.6x10^{-5}$
108952	Phenol	$1.2x10^{-7}$	$6.4x10^{-7}$	$6.9x10^{-7}$
129000	Pyrene	$4.8x10^{-6}$	$2.6x10^{-5}$	$2.8x10^{-5}$
132649	Dibenzofuran	$1.8x10^{-9}$	$9.6x10^{-9}$	$1.0x10^{-8}$
193395	Indeno(1,2,3-cd)pyrene	$7.5x10^{-7}$	$3.9x10^{-6}$	$4.3x10^{-6}$
205992	Benzo(b)fluoranthene	$1.4x10^{-6}$	$7.2x10^{-6}$	$7.8x10^{-6}$
206440	Fluoranthene	$4.6x10^{-6}$	$2.4x10^{-5}$	$2.6x10^{-5}$
207089	Benzo(k)fluoranthene	$1.2x10^{-6}$	$6.3x10^{-6}$	$6.8x10^{-6}$
218019	Chrysene	$2.2x10^{-6}$	$1.2x10^{-5}$	$1.3x10^{-5}$
463581	Carbonyl sulfide	$2.0x10^{-7}$	$1.1x10^{-6}$	$1.2x10^{-6}$
1330207	Xylene (mixed isomers)	$1.0x10^{-6}$	$5.3x10^{-6}$	$5.8x10^{-6}$
7440382	Arsenic	$4.0x10^{-11}$	$2.1x10^{-10}$	$2.3x10^{-10}$
7647010	Hydrochloric acid	$1.8x10^{-7}$	$9.6x10^{-7}$	$1.0x10^{-6}$
7664393	Hydrofluoric acid	$1.0x10^{-9}$	$5.3x10^{-9}$	$5.8x10^{-9}$
7782492	Selenium	$4.0x10^{-11}$	$2.1x10^{-10}$	$2.3x10^{-10}$

Table C-37 MACT I Emissions from Coke Battery No.4 - Battery offtakes at AK Steel Ashland

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$2.3x10^{-3}$	$3.2x10^{-3}$	$3.2x10^{-3}$
50328	Benzo(a)pyrene	$1.9x10^{-5}$	$2.7x10^{-5}$	$2.7x10^{-5}$
56553	Benzo(a)anthracene	$2.1x10^{-5}$	$2.8x10^{-5}$	$2.8x10^{-5}$
71432	Benzene	$1.2x10^{-3}$	$1.6x10^{-3}$	$1.6x10^{-3}$
74908	Hydrocyanic acid	$1.2x10^{-4}$	$1.6x10^{-4}$	$1.6x10^{-4}$
75150	Carbon disulfide	$2.3x10^{-6}$	$3.2x10^{-6}$	$3.2x10^{-6}$
85018	Phenanthrene	$9.7x10^{-5}$	$1.3x10^{-4}$	$1.3x10^{-4}$
86737	Fluorene	$2.5x10^{-5}$	$3.5x10^{-5}$	$3.5x10^{-5}$
91203	Naphthalene	$2.4x10^{-4}$	$3.3x10^{-4}$	$3.3x10^{-4}$
95487	Cresol, o-	$1.6x10^{-7}$	$2.2x10^{-7}$	$2.2x10^{-7}$
98828	Cumene	$6.9x10^{-6}$	$9.5x10^{-6}$	$9.5x10^{-6}$
106445	Cresol, p-	$4.6x10^{-7}$	$6.3x10^{-7}$	$6.3x10^{-7}$
106990	1,3-Butadiene	$2.1x10^{-5}$	$2.8x10^{-5}$	$2.8x10^{-5}$
108883	Toluene	$9.2x10^{-5}$	$1.3x10^{-4}$	$1.3x10^{-4}$
108952	Phenol	$1.4x10^{-6}$	$1.9x10^{-6}$	$1.9x10^{-6}$
129000	Pyrene	$5.5x10^{-5}$	$7.6x10^{-5}$	$7.6x10^{-5}$
132649	Dibenzofuran	$2.1x10^{-8}$	$2.8x10^{-8}$	$2.8x10^{-8}$
193395	Indeno(1,2,3-cd)pyrene	$8.5x10^{-6}$	$1.2x10^{-5}$	$1.2x10^{-5}$
205992	Benzo(b)fluoranthene	$1.6x10^{-5}$	$2.2x10^{-5}$	$2.2x10^{-5}$
206440	Fluoranthene	$5.3x10^{-5}$	$7.3x10^{-5}$	$7.3x10^{-5}$
207089	Benzo(k)fluoranthene	$1.4x10^{-5}$	$1.9x10^{-5}$	$1.9x10^{-5}$
218019	Chrysene	$2.5x10^{-5}$	$3.5x10^{-5}$	$3.5x10^{-5}$
463581	Carbonyl sulfide	$2.3x10^{-6}$	$3.2x10^{-6}$	$3.2x10^{-6}$
1330207	Xylene (mixed isomers)	$1.2x10^{-5}$	$1.6x10^{-5}$	$1.6x10^{-5}$
7440382	Arsenic	$4.6x10^{-10}$	$6.3x10^{-10}$	$6.3x10^{-10}$
7647010	Hydrochloric acid	$2.1x10^{-6}$	$2.8x10^{-6}$	$2.8x10^{-6}$
7664393	Hydrofluoric acid	$1.2x10^{-8}$	$1.6x10^{-8}$	$1.6x10^{-8}$
7782492	Selenium	$4.6x10^{-10}$	$6.3x10^{-10}$	$6.3x10^{-10}$

Table C-38 MACT I Emissions from Coke Battery - Battery charging at Erie Coke

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	3.7×10^{-4}	1.2×10^{-3}	1.2×10^{-3}
50328	Benzo(a)pyrene	3.1×10^{-6}	9.7×10^{-6}	9.7×10^{-6}
56553	Benzo(a)anthracene	3.4×10^{-6}	1.0×10^{-5}	1.0×10^{-5}
71432	Benzene	1.9×10^{-4}	5.8×10^{-4}	5.8×10^{-4}
74908	Hydrocyanic acid	1.9×10^{-5}	5.8×10^{-5}	5.8×10^{-5}
75150	Carbon disulfide	3.7×10^{-7}	1.2×10^{-6}	1.2×10^{-6}
85018	Phenanthrene	1.6×10^{-5}	4.8×10^{-5}	4.8×10^{-5}
86737	Fluorene	4.1×10^{-6}	1.3×10^{-5}	1.3×10^{-5}
91203	Naphthalene	3.9×10^{-5}	1.2×10^{-4}	1.2×10^{-4}
95487	Cresol, o-	2.6×10^{-8}	8.1×10^{-8}	8.1×10^{-8}
98828	Cumene	1.1×10^{-6}	3.5×10^{-6}	3.5×10^{-6}
106445	Cresol, p-	7.5×10^{-8}	2.3×10^{-7}	2.3×10^{-7}
106990	1,3-Butadiene	3.4×10^{-6}	1.0×10^{-5}	1.0×10^{-5}
108883	Toluene	1.5×10^{-5}	4.6×10^{-5}	4.6×10^{-5}
108952	Phenol	2.2×10^{-7}	6.9×10^{-7}	6.9×10^{-7}
129000	Pyrene	9.0×10^{-6}	2.8×10^{-5}	2.8×10^{-5}
132649	Dibenzofuran	3.4×10^{-9}	1.0×10^{-8}	1.0×10^{-8}
193395	Indeno(1,2,3-cd)pyrene	1.4×10^{-6}	4.3×10^{-6}	4.3×10^{-6}
205992	Benzo(b)fluoranthene	2.5×10^{-6}	7.8×10^{-6}	7.8×10^{-6}
206440	Fluoranthene	8.6×10^{-6}	2.6×10^{-5}	2.6×10^{-5}
207089	Benzo(k)fluoranthene	2.2×10^{-6}	6.8×10^{-6}	6.8×10^{-6}
218019	Chrysene	4.1×10^{-6}	1.3×10^{-5}	1.3×10^{-5}
463581	Carbonyl sulfide	3.7×10^{-7}	1.2×10^{-6}	1.2×10^{-6}
1330207	Xylene (mixed isomers)	1.9×10^{-6}	5.8×10^{-6}	5.8×10^{-6}
7440382	Arsenic	7.5×10^{-11}	2.3×10^{-10}	2.3×10^{-10}
7647010	Hydrochloric acid	3.4×10^{-7}	1.0×10^{-6}	1.0×10^{-6}
7664393	Hydrofluoric acid	1.9×10^{-9}	5.8×10^{-9}	5.8×10^{-9}
7782492	Selenium	7.5×10^{-11}	2.3×10^{-10}	2.3×10^{-10}

Table C-39 MACT I Emissions from Coke Battery - Battery doors at Erie Coke

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$1.3x10^{-2}$	$2.0x10^{-2}$	$1.7x10^{-2}$
50328	Benzo(a)pyrene	$1.1x10^{-4}$	$1.6x10^{-4}$	$1.4x10^{-4}$
56553	Benzo(a)anthracene	$1.1x10^{-4}$	$1.8x10^{-4}$	$1.6x10^{-4}$
71432	Benzene	$6.3x10^{-3}$	$9.8x10^{-3}$	$8.6x10^{-3}$
74908	Hydrocyanic acid	$6.3x10^{-4}$	$9.8x10^{-4}$	$8.6x10^{-4}$
75150	Carbon disulfide	$1.3x10^{-5}$	$2.0x10^{-5}$	$1.7x10^{-5}$
85018	Phenanthrene	$5.3x10^{-4}$	$8.2x10^{-4}$	$7.2x10^{-4}$
86737	Fluorene	$1.4x10^{-4}$	$2.2x10^{-4}$	$1.9x10^{-4}$
91203	Naphthalene	$1.3x10^{-3}$	$2.1x10^{-3}$	$1.8x10^{-3}$
95487	Cresol, o-	$8.9x10^{-7}$	$1.4x10^{-6}$	$1.2x10^{-6}$
98828	Cumene	$3.8x10^{-5}$	$5.9x10^{-5}$	$5.2x10^{-5}$
106445	Cresol, p-	$2.5x10^{-6}$	$3.9x10^{-6}$	$3.5x10^{-6}$
106990	1,3-Butadiene	$1.1x10^{-4}$	$1.8x10^{-4}$	$1.6x10^{-4}$
108883	Toluene	$5.1x10^{-4}$	$7.8x10^{-4}$	$6.9x10^{-4}$
108952	Phenol	$7.6x10^{-6}$	$1.2x10^{-5}$	$1.0x10^{-5}$
129000	Pyrene	$3.0x10^{-4}$	$4.7x10^{-4}$	$4.1x10^{-4}$
132649	Dibenzofuran	$1.1x10^{-7}$	$1.8x10^{-7}$	$1.6x10^{-7}$
193395	Indeno(1,2,3-cd)pyrene	$4.7x10^{-5}$	$7.2x10^{-5}$	$6.4x10^{-5}$
205992	Benzo(b)fluoranthene	$8.6x10^{-5}$	$1.3x10^{-4}$	$1.2x10^{-4}$
206440	Fluoranthene	$2.9x10^{-4}$	$4.5x10^{-4}$	$4.0x10^{-4}$
207089	Benzo(k)fluoranthene	$7.5x10^{-5}$	$1.2x10^{-4}$	$1.0x10^{-4}$
218019	Chrysene	$1.4x10^{-4}$	$2.2x10^{-4}$	$1.9x10^{-4}$
463581	Carbonyl sulfide	$1.3x10^{-5}$	$2.0x10^{-5}$	$1.7x10^{-5}$
1330207	Xylene (mixed isomers)	$6.3x10^{-5}$	$9.8x10^{-5}$	$8.6x10^{-5}$
7440382	Arsenic	$2.5x10^{-9}$	$3.9x10^{-9}$	$3.5x10^{-9}$
7647010	Hydrochloric acid	$1.1x10^{-5}$	$1.8x10^{-5}$	$1.6x10^{-5}$
7664393	Hydrofluoric acid	$6.3x10^{-8}$	$9.8x10^{-8}$	$8.6x10^{-8}$
7782492	Selenium	$2.5x10^{-9}$	$3.9x10^{-9}$	$3.5x10^{-9}$

Table C-40 MACT I Emissions from Coke Battery A - Battery lids at Erie Coke

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$3.2x10^{-5}$	$5.2x10^{-4}$	$2.9x10^{-4}$
50328	Benzo(a)pyrene	$2.7x10^{-7}$	$4.3x10^{-6}$	$2.4x10^{-6}$
56553	Benzo(a)anthracene	$2.8x10^{-7}$	$4.7x10^{-6}$	$2.6x10^{-6}$
71432	Benzene	$1.6x10^{-5}$	$2.6x10^{-4}$	$1.4x10^{-4}$
74908	Hydrocyanic acid	$1.6x10^{-6}$	$2.6x10^{-5}$	$1.4x10^{-5}$
75150	Carbon disulfide	$3.2x10^{-8}$	$5.2x10^{-7}$	$2.9x10^{-7}$
85018	Phenanthrene	$1.3x10^{-6}$	$2.2x10^{-5}$	$1.2x10^{-5}$
86737	Fluorene	$3.5x10^{-7}$	$5.7x10^{-6}$	$3.2x10^{-6}$
91203	Naphthalene	$3.3x10^{-6}$	$5.4x10^{-5}$	$3.0x10^{-5}$
95487	Cresol, o-	$2.2x10^{-9}$	$3.6x10^{-8}$	$2.0x10^{-8}$
98828	Cumene	$9.5x10^{-8}$	$1.6x10^{-6}$	$8.6x10^{-7}$
106445	Cresol, p-	$6.3x10^{-9}$	$1.0x10^{-7}$	$5.8x10^{-8}$
106990	1,3-Butadiene	$2.8x10^{-7}$	$4.7x10^{-6}$	$2.6x10^{-6}$
108883	Toluene	$1.3x10^{-6}$	$2.1x10^{-5}$	$1.2x10^{-5}$
108952	Phenol	$1.9x10^{-8}$	$3.1x10^{-7}$	$1.7x10^{-7}$
129000	Pyrene	$7.6x10^{-7}$	$1.2x10^{-5}$	$6.9x10^{-6}$
132649	Dibenzofuran	$2.8x10^{-10}$	$4.7x10^{-9}$	$2.6x10^{-9}$
193395	Indeno(1,2,3-cd)pyrene	$1.2x10^{-7}$	$1.9x10^{-6}$	$1.1x10^{-6}$
205992	Benzo(b)fluoranthene	$2.2x10^{-7}$	$3.5x10^{-6}$	$2.0x10^{-6}$
206440	Fluoranthene	$7.3x10^{-7}$	$1.2x10^{-5}$	$6.6x10^{-6}$
207089	Benzo(k)fluoranthene	$1.9x10^{-7}$	$3.1x10^{-6}$	$1.7x10^{-6}$
218019	Chrysene	$3.5x10^{-7}$	$5.7x10^{-6}$	$3.2x10^{-6}$
463581	Carbonyl sulfide	$3.2x10^{-8}$	$5.2x10^{-7}$	$2.9x10^{-7}$
1330207	Xylene (mixed isomers)	$1.6x10^{-7}$	$2.6x10^{-6}$	$1.4x10^{-6}$
7440382	Arsenic	$6.3x10^{-12}$	$1.0x10^{-10}$	$5.8x10^{-11}$
7647010	Hydrochloric acid	$2.8x10^{-8}$	$4.7x10^{-7}$	$2.6x10^{-7}$
7664393	Hydrofluoric acid	$1.6x10^{-10}$	$2.6x10^{-9}$	$1.4x10^{-9}$
7782492	Selenium	$6.3x10^{-12}$	$1.0x10^{-10}$	$5.8x10^{-11}$

Table C-41 MACT I Emissions from Coke Battery A - Battery offtakes at Erie Coke

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	1.3x10^{-4}	5.8x10^{-4}	5.8x10^{-4}
50328	Benzo(a)pyrene	1.1x10^{-6}	4.8x10^{-6}	4.8x10^{-6}
56553	Benzo(a)anthracene	1.2x10^{-6}	5.2x10^{-6}	5.2x10^{-6}
71432	Benzene	6.6x10^{-5}	2.9x10^{-4}	2.9x10^{-4}
74908	Hydrocyanic acid	6.6x10^{-6}	2.9x10^{-5}	2.9x10^{-5}
75150	Carbon disulfide	1.3x10^{-7}	5.8x10^{-7}	5.8x10^{-7}
85018	Phenanthrene	5.6x10^{-6}	2.4x10^{-5}	2.4x10^{-5}
86737	Fluorene	1.5x10^{-6}	6.3x10^{-6}	6.3x10^{-6}
91203	Naphthalene	1.4x10^{-5}	6.0x10^{-5}	6.0x10^{-5}
95487	Cresol, o-	9.3x10^{-9}	4.0x10^{-8}	4.0x10^{-8}
98828	Cumene	4.0x10^{-7}	1.7x10^{-6}	1.7x10^{-6}
106445	Cresol, p-	2.6x10^{-8}	1.2x10^{-7}	1.2x10^{-7}
106990	1,3-Butadiene	1.2x10^{-6}	5.2x10^{-6}	5.2x10^{-6}
108883	Toluene	5.3x10^{-6}	2.3x10^{-5}	2.3x10^{-5}
108952	Phenol	7.9x10^{-8}	3.5x10^{-7}	3.5x10^{-7}
129000	Pyrene	3.2x10^{-6}	1.4x10^{-5}	1.4x10^{-5}
132649	Dibenzofuran	1.2x10^{-9}	5.2x10^{-9}	5.2x10^{-9}
193395	Indeno(1,2,3-cd)pyrene	4.9x10^{-7}	2.1x10^{-6}	2.1x10^{-6}
205992	Benzo(b)fluoranthene	9.0x10^{-7}	3.9x10^{-6}	3.9x10^{-6}
206440	Fluoranthene	3.0x10^{-6}	1.3x10^{-5}	1.3x10^{-5}
207089	Benzo(k)fluoranthene	7.8x10^{-7}	3.4x10^{-6}	3.4x10^{-6}
218019	Chrysene	1.5x10^{-6}	6.3x10^{-6}	6.3x10^{-6}
463581	Carbonyl sulfide	1.3x10^{-7}	5.8x10^{-7}	5.8x10^{-7}
1330207	Xylene (mixed isomers)	6.6x10^{-7}	2.9x10^{-6}	2.9x10^{-6}
7440382	Arsenic	2.6x10^{-11}	1.2x10^{-10}	1.2x10^{-10}
7647010	Hydrochloric acid	1.2x10^{-7}	5.2x10^{-7}	5.2x10^{-7}
7664393	Hydrofluoric acid	6.6x10^{-10}	2.9x10^{-9}	2.9x10^{-9}
7782492	Selenium	2.6x10^{-11}	1.2x10^{-10}	1.2x10^{-10}

Table C-42 MACT I Emissions from Coke Battery B - Battery Charging at Erie Coke

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	5.5x10^{-4}	1.7x10^{-3}	1.7x10^{-3}
50328	Benzo(a)pyrene	4.6x10^{-6}	1.4x10^{-5}	1.4x10^{-5}
56553	Benzo(a)anthracene	4.9x10^{-6}	1.6x10^{-5}	1.6x10^{-5}
71432	Benzene	2.7x10^{-4}	8.6x10^{-4}	8.6x10^{-4}
74908	Hydrocyanic acid	2.7x10^{-5}	8.6x10^{-5}	8.6x10^{-5}
75150	Carbon disulfide	5.5x10^{-7}	1.7x10^{-6}	1.7x10^{-6}
85018	Phenanthrene	2.3x10^{-5}	7.2x10^{-5}	7.2x10^{-5}
86737	Fluorene	6.0x10^{-6}	1.9x10^{-5}	1.9x10^{-5}
91203	Naphthalene	5.7x10^{-5}	1.8x10^{-4}	1.8x10^{-4}
95487	Cresol, o-	3.8x10^{-8}	1.2x10^{-7}	1.2x10^{-7}
98828	Cumene	1.6x10^{-6}	5.2x10^{-6}	5.2x10^{-6}
106445	Cresol, p-	1.1x10^{-7}	3.5x10^{-7}	3.5x10^{-7}
106990	1,3-Butadiene	4.9x10^{-6}	1.6x10^{-5}	1.6x10^{-5}
108883	Toluene	2.2x10^{-5}	6.9x10^{-5}	6.9x10^{-5}
108952	Phenol	3.3x10^{7}	1.0x10^{-6}	1.0x10^{-6}
129000	Pyrene	1.3x10^{-5}	4.1x10^{-5}	4.1x10^{-5}
132649	Dibenzofuran	4.9x10^{-9}	1.6x10^{-8}	1.6x10^{-8}
193395	Indeno(1,2,3-cd)pyrene	2.0x10^{-6}	6.4x10^{-6}	6.4x10^{-6}
205992	Benzo(b)fluoranthene	3.7x10^{-6}	1.2x10^{-5}	1.2x10^{-5}
206440	Fluoranthene	1.3x10^{-5}	4.0x10^{-5}	4.0x10^{-5}
207089	Benzo(k)fluoranthene	3.2x10^{-6}	1.0x10^{-5}	1.0x10^{-5}
218019	Chrysene	6.0x10^{-6}	1.9x10^{-5}	1.9x10^{-5}
463581	Carbonyl sulfide	5.5x10^{-7}	1.7x10^{-6}	1.7x10^{-6}
1330207	Xylene (mixed isomers)	2.7x10^{-6}	8.6x10^{-6}	8.6x10^{-6}
7440382	Arsenic	1.1x10^{-10}	3.5x10^{-10}	3.5x10^{-10}
7647010	Hydrochloric acid	4.9x10^{-7}	1.6x10^{-6}	1.6x10^{-6}
7664393	Hydrofluoric acid	2.7x10^{-9}	8.6x10^{-9}	8.6x10^{-9}
7782492	Selenium	1.1x10^{-10}	3.5x10^{-10}	3.5x10^{-10}

Table C-43 MACT I Emissions from Coke Battery B - Battery Doors at Erie Coke

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$1.8\text{x}10^{-2}$	$3.0\text{x}10^{-2}$	$2.6\text{x}10^{-2}$
50328	Benzo(a)pyrene	$1.5\text{x}10^{-4}$	$2.5\text{x}10^{-4}$	$2.2\text{x}10^{-4}$
56553	Benzo(a)anthracene	$1.6\text{x}10^{-4}$	$2.7\text{x}10^{-4}$	$2.4\text{x}10^{-4}$
71432	Benzene	$8.9\text{x}10^{-3}$	$1.5\text{x}10^{-2}$	$1.3\text{x}10^{-2}$
74908	Hydrocyanic acid	$8.9\text{x}10^{-4}$	$1.5\text{x}10^{-3}$	$1.3\text{x}10^{-3}$
75150	Carbon disulfide	$1.8\text{x}10^{-5}$	$3.0\text{x}10^{-5}$	$2.6\text{x}10^{-5}$
85018	Phenanthrene	$7.5\text{x}10^{-4}$	$1.3\text{x}10^{-3}$	$1.1\text{x}10^{-3}$
86737	Fluorene	$2.0\text{x}10^{-4}$	$3.3\text{x}10^{-4}$	$2.9\text{x}10^{-4}$
91203	Naphthalene	$1.9\text{x}10^{-3}$	$3.1\text{x}10^{-3}$	$2.7\text{x}10^{-3}$
95487	Cresol, o-	$1.2\text{x}10^{-6}$	$2.1\text{x}10^{-6}$	$1.8\text{x}10^{-6}$
98828	Cumene	$5.4\text{x}10^{-5}$	$9.0\text{x}10^{-5}$	$7.9\text{x}10^{-5}$
106445	Cresol, p-	$3.6\text{x}10^{-6}$	$6.0\text{x}10^{-6}$	$5.2\text{x}10^{-6}$
106990	1,3-Butadiene	$1.6\text{x}10^{-4}$	$2.7\text{x}10^{-4}$	$2.4\text{x}10^{-4}$
108883	Toluene	$7.1\text{x}10^{-4}$	$1.2\text{x}10^{-3}$	$1.0\text{x}10^{-3}$
108952	Phenol	$1.1\text{x}10^{-5}$	$1.8\text{x}10^{-5}$	$1.6\text{x}10^{-5}$
129000	Pyrene	$4.3\text{x}10^{-4}$	$7.2\text{x}10^{-4}$	$6.3\text{x}10^{-4}$
132649	Dibenzofuran	$1.6\text{x}10^{-7}$	$2.7\text{x}10^{-7}$	$2.4\text{x}10^{-7}$
193395	Indeno(1,2,3-cd)pyrene	$6.6\text{x}10^{-5}$	$1.1\text{x}10^{-4}$	$9.7\text{x}10^{-5}$
205992	Benzo(b)fluoranthene	$2.2\text{x}10^{-4}$	$2.0\text{x}10^{-4}$	$1.8\text{x}10^{-4}$
206440	Fluoranthene	$4.1\text{x}10^{-4}$	$6.9\text{x}10^{-4}$	$6.0\text{x}10^{-4}$
207089	Benzo(k)fluoranthene	$1.1\text{x}10^{-4}$	$1.8\text{x}10^{-4}$	$1.5\text{x}10^{-4}$
218019	Chrysene	$2.0\text{x}10^{-4}$	$3.3\text{x}10^{-4}$	$2.9\text{x}10^{-4}$
463581	Carbonyl sulfide	$1.8\text{x}10^{-5}$	$3.0\text{x}10^{-5}$	$2.6\text{x}10^{-5}$
1330207	Xylene (mixed isomers)	$8.9\text{x}10^{-5}$	$1.5\text{x}10^{-4}$	$1.3\text{x}10^{-4}$
7440382	Arsenic	$3.6\text{x}10^{-9}$	$6.0\text{x}10^{-9}$	$5.2\text{x}10^{-9}$
7647010	Hydrochloric acid	$1.6\text{x}10^{-5}$	$2.7\text{x}10^{-5}$	$2.4\text{x}10^{-5}$
7664393	Hydrofluoric acid	$8.9\text{x}10^{-8}$	$1.5\text{x}10^{-7}$	$1.3\text{x}10^{-7}$
7782492	Selenium	$3.6\text{x}10^{-9}$	$6.0\text{x}10^{-9}$	$5.2\text{x}10^{-9}$

Table C-44 MACT I Emissions from Coke Battery B - Battery Lids at Erie Coke

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	7.5x10^{-5}	8.1x10^{-4}	5.8x10^{-4}
50328	Benzo(a)pyrene	6.3x10^{-7}	6.8x10^{-6}	4.8x10^{-6}
56553	Benzo(a)anthracene	6.7x10^{-7}	7.2x10^{-6}	5.2x10^{-6}
71432	Benzene	3.7x10^{-5}	4.0x10^{-4}	2.9x10^{-4}
74908	Hydrocyanic acid	3.7x10^{-6}	4.0x10^{-5}	2.9x10^{-5}
75150	Carbon disulfide	7.5x10^{-8}	8.1x10^{-7}	5.8x10^{-7}
85018	Phenanthrene	3.1x10^{-6}	3.4x10^{-5}	2.4x10^{-5}
86737	Fluorene	8.2x10^{-7}	8.9x10^{-6}	6.3x10^{-6}
91203	Naphthalene	7.9x10^{-6}	8.5x10^{-5}	6.0x10^{-5}
95487	Cresol, o-	5.2x10^{-9}	5.6x10^{-8}	4.0x10^{-8}
98828	Cumene	2.2x10^{-7}	2.4x10^{-6}	1.7x10^{-6}
106445	Cresol, p-	1.5x10^{-8}	1.6x10^{-7}	1.2x10^{-7}
106990	1,3-Butadiene	6.7x10^{-7}	7.2x10^{-6}	5.2x10^{-6}
108883	Toluene	3.0x10^{-6}	3.2x10^{-5}	2.3x10^{-5}
108952	Phenol	4.5x10^{-8}	4.8x10^{-7}	3.5x10^{-7}
129000	Pyrene	1.8x10^{-6}	1.9x10^{-5}	1.4x10^{-5}
132649	Dibenzofuran	6.7x10^{-10}	7.2x10^{-9}	5.2x10^{-9}
193395	Indeno(1,2,3-cd)pyrene	2.8x10^{-7}	3.0x10^{-6}	2.1x10^{-6}
205992	Benzo(b)fluoranthene	5.1x10^{-7}	5.5x10^{-6}	3.9x10^{-6}
206440	Fluoranthene	1.7x10^{-6}	1.9x10^{-5}	1.3x10^{-5}
207089	Benzo(k)fluoranthene	4.4x10^{-7}	4.8x10^{-6}	3.4x10^{-6}
218019	Chrysene	8.2x10^{-7}	8.9x10^{-6}	6.3x10^{-6}
463581	Carbonyl sulfide	7.5x10^{-8}	8.1x10^{-7}	5.8x10^{-7}
1330207	Xylene (mixed isomers)	3.7x10^{-7}	4.0x10^{-6}	2.9x10^{-6}
7440382	Arsenic	1.5x10^{-11}	1.6x10^{-10}	1.2x10^{-10}
7647010	Hydrochloric acid	6.7x10^{-8}	7.2x10^{-7}	5.2x10^{-7}
7664393	Hydrofluoric acid	3.7x10^{-10}	4.0x10^{-9}	2.9x10^{-9}
7782492	Selenium	1.5x10^{-11}	1.6x10^{-10}	1.2x10^{-10}

Table C-45 MACT I Emissions from Coke Battery B - Battery offtakes at Erie Coke

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$2.9x10^{-4}$	$8.6x10^{-4}$	$8.6x10^{-4}$
50328	Benzo(a)pyrene	$2.4x10^{-6}$	$7.2x10^{-6}$	$7.2x10^{-6}$
56553	Benzo(a)anthracene	$2.6x10^{-6}$	$7.8x10^{-6}$	$7.8x10^{-6}$
71432	Benzene	$1.4x10^{-4}$	$4.3x10^{-4}$	$4.3x10^{-4}$
74908	Hydrocyanic acid	$1.4x10^{-5}$	$4.3x10^{-5}$	$4.3x10^{-5}$
75150	Carbon disulfide	$2.9x10^{-7}$	$8.6x10^{-7}$	$8.6x10^{-7}$
85018	Phenanthrene	$1.2x10^{-5}$	$3.6x10^{-5}$	$3.6x10^{-5}$
86737	Fluorene	$3.2x10^{-6}$	$9.5x10^{-6}$	$9.5x10^{-6}$
91203	Naphthalene	$3.0x10^{-5}$	$9.1x10^{-5}$	$9.1x10^{-5}$
95487	Cresol, o-	$2.0x10^{-8}$	$6.0x10^{-8}$	$6.0x10^{-8}$
98828	Cumene	$8.6x10^{-7}$	$2.6x10^{-6}$	$2.6x10^{-6}$
106445	Cresol, p-	$5.8x10^{-8}$	$1.7x10^{-7}$	$1.7x10^{-7}$
106990	1,3-Butadiene	$2.6x10^{-6}$	$7.8x10^{-6}$	$7.8x10^{-6}$
108883	Toluene	$1.2x10^{-5}$	$3.5x10^{-5}$	$3.5x10^{-5}$
108952	Phenol	$1.7x10^{-7}$	$5.2x10^{-7}$	$5.2x10^{-7}$
129000	Pyrene	$6.9x10^{-6}$	$2.1x10^{-5}$	$2.1x10^{-5}$
132649	Dibenzofuran	$2.6x10^{-9}$	$7.8x10^{-9}$	$7.8x10^{-9}$
193395	Indeno(1,2,3-cd)pyrene	$1.1x10^{-6}$	$3.2x10^{-6}$	$3.2x10^{-6}$
205992	Benzo(b)fluoranthene	$2.0x10^{-6}$	$5.9x10^{-6}$	$5.9x10^{-6}$
206440	Fluoranthene	$6.6x10^{-6}$	$2.0x10^{-5}$	$2.0x10^{-5}$
207089	Benzo(k)fluoranthene	$1.7x10^{-6}$	$5.1x10^{-6}$	$5.1x10^{-6}$
218019	Chrysene	$3.2x10^{-6}$	$9.5x10^{-6}$	$9.5x10^{-6}$
463581	Carbonyl sulfide	$2.9x10^{-7}$	$8.6x10^{-7}$	$8.6x10^{-7}$
1330207	Xylene (mixed isomers)	$1.4x10^{-6}$	$4.3x10^{-6}$	$4.3x10^{-6}$
7440382	Arsenic	$5.8x10^{-11}$	$1.7x10^{-10}$	$1.7x10^{-10}$
7647010	Hydrochloric acid	$2.6x10^{-7}$	$7.8x10^{-7}$	$7.8x10^{-7}$
7664393	Hydrofluoric acid	$1.4x10^{-9}$	$4.3x10^{-9}$	$4.3x10^{-9}$
7782492	Selenium	$5.8x10^{-11}$	$1.7x10^{-10}$	$1.7x10^{-10}$

Table C-46 MACT I Emissions from Coke Battery - Battery Charging at Tonawanda

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$5.8x10^{-4}$	$2.9x10^{-3}$	$2.9x10^{-3}$
50328	Benzo(a)pyrene	$4.8x10^{-6}$	$2.4x10^{-5}$	$2.4x10^{-5}$
56553	Benzo(a)anthracene	$5.2x10^{-6}$	$2.6x10^{-5}$	$2.6x10^{-5}$
71432	Benzene	$2.9x10^{-4}$	$1.4x10^{-3}$	$1.4x10^{-3}$
74908	Hydrocyanic acid	$2.9x10^{-5}$	$1.4x10^{-4}$	$1.4x10^{-4}$
75150	Carbon disulfide	$5.8x10^{-7}$	$2.9x10^{-6}$	$2.9x10^{-6}$
85018	Phenanthrene	$2.4x10^{-5}$	$1.2x10^{-4}$	$1.2x10^{-4}$
86737	Fluorene	$6.3x10^{-6}$	$3.2x10^{-5}$	$3.2x10^{-5}$
91203	Naphthalene	$6.0x10^{-5}$	$3.0x10^{-4}$	$3.0x10^{-4}$
95487	Cresol, o-	$4.0x10^{-8}$	$2.0x10^{-7}$	$2.0x10^{-7}$
98828	Cumene	$1.7x10^{-6}$	$8.6x10^{-6}$	$8.6x10^{-6}$
106445	Cresol, p-	$1.2x10^{-7}$	$5.8x10^{-7}$	$5.8x10^{-7}$
106990	1,3-Butadiene	$5.2x10^{-6}$	$2.6x10^{-5}$	$2.6x10^{-5}$
108883	Toluene	$2.3x10^{-5}$	$1.2x10^{-4}$	$1.2x10^{-4}$
108952	Phenol	$3.5x10^{-7}$	$1.7x10^{-6}$	$1.7x10^{-6}$
129000	Pyrene	$1.4x10^{-5}$	$6.9x10^{-5}$	$6.9x10^{-5}$
132649	Dibenzofuran	$5.2x10^{-9}$	$2.6x10^{-8}$	$2.6x10^{-8}$
193395	Indeno(1,2,3-cd)pyrene	$2.1x10^{-6}$	$1.1x10^{-5}$	$1.1x10^{-5}$
205992	Benzo(b)fluoranthene	$3.9x10^{-6}$	$2.0x10^{-5}$	$2.0x10^{-5}$
206440	Fluoranthene	$1.3x10^{-5}$	$6.6x10^{-5}$	$6.6x10^{-5}$
207089	Benzo(k)fluoranthene	$3.4x10^{-6}$	$1.7x10^{-5}$	$1.7x10^{-5}$
218019	Chrysene	$6.3x10^{-6}$	$3.2x10^{-5}$	$3.2x10^{-5}$
463581	Carbonyl sulfide	$5.8x10^{-7}$	$2.9x10^{-6}$	$2.9x10^{-6}$
1330207	Xylene (mixed isomers)	$2.9x10^{-6}$	$1.4x10^{-5}$	$1.4x10^{-5}$
7440382	Arsenic	$1.2x10^{-10}$	$5.8x10^{-10}$	$5.8x10^{-10}$
7647010	Hydrochloric acid	$5.2x10^{-7}$	$2.6x10^{-6}$	$2.6x10^{-6}$
7664393	Hydrofluoric acid	$2.9x10^{-9}$	$1.4x10^{-8}$	$1.4x10^{-8}$
7782492	Selenium	$1.2x10^{-10}$	$5.8x10^{-10}$	$5.8x10^{-10}$

Table C-47 MACT I Emissions from Coke Battery - Battery Doors at Tonawanda

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	3.6×10^{-2}	5.1×10^{-2}	4.5×10^{-2}
50328	Benzo(a)pyrene	3.0×10^{-4}	4.3×10^{-4}	3.8×10^{-4}
56553	Benzo(a)anthracene	3.2×10^{-4}	4.6×10^{-4}	4.1×10^{-4}
71432	Benzene	1.8×10^{-2}	2.6×10^{-2}	2.3×10^{-2}
74908	Hydrocyanic acid	1.8×10^{-3}	2.6×10^{-3}	2.3×10^{-3}
75150	Carbon disulfide	3.6×10^{-5}	5.1×10^{-5}	4.5×10^{-5}
85018	Phenanthrene	1.5×10^{-3}	2.2×10^{-3}	1.9×10^{-3}
86737	Fluorene	4.0×10^{-4}	5.6×10^{-4}	5.0×10^{-4}
91203	Naphthalene	3.8×10^{-3}	5.4×10^{-3}	4.7×10^{-3}
95487	Cresol, o-	2.5×10^{-6}	3.6×10^{-6}	3.2×10^{-6}
98828	Cumene	1.1×10^{-4}	1.5×10^{-4}	1.4×10^{-4}
106445	Cresol, p-	7.2×10^{-6}	1.0×10^{-5}	9.0×10^{-6}
106990	1,3-Butadiene	3.2×10^{-4}	4.6×10^{-4}	4.1×10^{-4}
108883	Toluene	1.4×10^{-3}	2.0×10^{-3}	1.8×10^{-3}
108952	Phenol	2.2×10^{-5}	3.1×10^{-5}	2.7×10^{-5}
129000	Pyrene	8.6×10^{-4}	1.2×10^{-3}	1.1×10^{-3}
132649	Dibenzofuran	3.2×10^{-7}	4.6×10^{-7}	4.1×10^{-7}
193395	Indeno(1,2,3-cd)pyrene	1.3×10^{-4}	1.9×10^{-4}	1.7×10^{-4}
205992	Benzo(b)fluoranthene	2.4×10^{-4}	3.5×10^{-4}	3.1×10^{-4}
206440	Fluoranthene	8.3×10^{-4}	1.2×10^{-3}	1.0×10^{-3}
207089	Benzo(k)fluoranthene	2.1×10^{-4}	3.0×10^{-4}	2.7×10^{-4}
218019	Chrysene	4.0×10^{-4}	5.6×10^{-4}	5.0×10^{-4}
463581	Carbonyl sulfide	3.6×10^{-5}	5.1×10^{-5}	4.5×10^{-5}
1330207	Xylene (mixed isomers)	1.8×10^{-4}	2.6×10^{-4}	2.3×10^{-4}
7440382	Arsenic	7.2×10^{-9}	1.0×10^{-8}	9.0×10^{-9}
7647010	Hydrochloric acid	3.2×10^{-5}	4.6×10^{-5}	4.1×10^{-5}
7664393	Hydrofluoric acid	1.8×10^{-7}	2.6×10^{-7}	2.3×10^{-7}
7782492	Selenium	7.2×10^{-9}	1.0×10^{-8}	9.0×10^{-9}

Table C-48 MACT I Emissions from Coke Battery - Battery Lids at Tonawanda

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	5.8x10^{-5}	1.0x10^{-3}	5.8x10^{-4}
50328	Benzo(a)pyrene	4.8x10^{-7}	8.5x10^{-6}	4.8x10^{-6}
56553	Benzo(a)anthracene	5.2x10^{-7}	9.1x10^{-6}	5.2x10^{-6}
71432	Benzene	2.9x10^{-5}	5.0x10^{-4}	2.9x10^{-4}
74908	Hydrocyanic acid	2.9x10^{-6}	5.0x10^{-5}	2.9x10^{-5}
75150	Carbon disulfide	5.8x10^{-8}	1.0x10^{-6}	5.8x10^{-7}
85018	Phenanthrene	2.4x10^{-6}	4.2x10^{-5}	2.4x10^{-5}
86737	Fluorene	6.3x10^{-7}	1.1x10^{-5}	6.3x10^{-6}
91203	Naphthalene	6.0x10^{-6}	1.1x10^{-4}	6.0x10^{-5}
95487	Cresol, o-	4.0x10^{-9}	7.0x10^{-8}	4.0x10^{-8}
98828	Cumene	1.7x10^{-7}	3.0x10^{-6}	1.7x10^{-6}
106445	Cresol, p-	1.2x10^{-8}	2.0x10^{-7}	1.2x10^{-7}
106990	1,3-Butadiene	5.2x10^{-7}	9.1x10^{-6}	5.2x10^{-6}
108883	Toluene	2.3x10^{-6}	4.0x10^{-5}	2.3x10^{-5}
108952	Phenol	3.5x10^{-8}	6.0x10^{-7}	3.5x10^{-7}
129000	Pyrene	1.4x10^{-6}	2.4x10^{-5}	1.4x10^{-5}
132649	Dibenzofuran	5.2x10^{-10}	9.1x10^{-9}	5.2x10^{-9}
193395	Indeno(1,2,3-cd)pyrene	2.1x10^{-7}	3.7x10^{-6}	2.1x10^{-6}
205992	Benzo(b)fluoranthene	3.9x10^{-7}	6.8x10^{-6}	3.9x10^{-6}
206440	Fluoranthene	1.3x10^{-6}	2.3x10^{-5}	1.3x10^{-5}
207089	Benzo(k)fluoranthene	3.4x10^{-7}	5.9x10^{-6}	3.4x10^{-6}
218019	Chrysene	6.3x10^{-7}	1.1x10^{-5}	6.3x10^{-6}
463581	Carbonyl sulfide	5.8x10^{-8}	1.0x10^{-6}	5.8x10^{-7}
1330207	Xylene (mixed isomers)	2.9x10^{-7}	5.0x10^{-6}	2.9x10^{-6}
7440382	Arsenic	1.2x10^{-11}	2.0x10^{-10}	1.2x10^{-10}
7647010	Hydrochloric acid	5.2x10^{-8}	9.1x10^{-7}	5.2x10^{-7}
7664393	Hydrofluoric acid	2.9x10^{-10}	5.0x10^{-9}	2.9x10^{-9}
7782492	Selenium	1.2x10^{-11}	2.0x10^{-10}	1.2x10^{-10}

Table C-49 MACT I Emissions from Coke Battery - Battery offtakes at Tonawanda

CAS #	Constituent	Emission Rate (g/s)		
		Actual	MACT	LAER
99992	Benzene soluble organics	$1.8x10^{-4}$	$1.7x10^{-3}$	$1.4x10^{-3}$
50328	Benzo(a)pyrene	$1.5x10^{-6}$	$1.4x10^{-5}$	$1.2x10^{-5}$
56553	Benzo(a)anthracene	$1.7x10^{-6}$	$1.6x10^{-5}$	$1.3x10^{-5}$
71432	Benzene	$9.2x10^{-5}$	$8.6x10^{-4}$	$7.2x10^{-4}$
74908	Hydrocyanic acid	$9.2x10^{-6}$	$8.6x10^{-5}$	$7.2x10^{-5}$
75150	Carbon disulfide	$1.8x10^{-7}$	$1.7x10^{-6}$	$1.4x10^{-6}$
85018	Phenanthrene	$7.7x10^{-6}$	$7.2x10^{-5}$	$6.0x10^{-5}$
86737	Fluorene	$2.0x10^{-6}$	$1.9x10^{-5}$	$1.6x10^{-5}$
91203	Naphthalene	$1.9x10^{-5}$	$1.8x10^{-4}$	$1.5x10^{-4}$
95487	Cresol, o-	$1.3x10^{-8}$	$1.2x10^{-7}$	$1.0x10^{-7}$
98828	Cumene	$5.5x10^{-7}$	$5.2x10^{-6}$	$4.3x10^{-6}$
106445	Cresol, p-	$3.7x10^{-8}$	$3.5x10^{-7}$	$2.9x10^{-7}$
106990	1,3-Butadiene	$1.7x10^{-6}$	$1.6x10^{-5}$	$1.3x10^{-5}$
108883	Toluene	$7.4x10^{-6}$	$6.9x10^{-5}$	$5.8x10^{-5}$
108952	Phenol	$1.1x10^{-7}$	$1.0x10^{-6}$	$8.6x10^{-7}$
129000	Pyrene	$4.4x10^{-6}$	$4.1x10^{-5}$	$3.5x10^{-5}$
132649	Dibenzofuran	$1.7x10^{-9}$	$1.6x10^{-8}$	$1.3x10^{-8}$
193395	Indeno(1,2,3-cd)pyrene	$6.8x10^{-7}$	$6.4x10^{-6}$	$5.3x10^{-6}$
205992	Benzo(b)fluoranthene	$1.3x10^{-6}$	$1.2x10^{-5}$	$9.8x10^{-6}$
206440	Fluoranthene	$4.2x10^{-6}$	$4.0x10^{-5}$	$3.3x10^{-5}$
207089	Benzo(k)fluoranthene	$1.1x10^{-6}$	$1.0x10^{-5}$	$8.5x10^{-6}$
218019	Chrysene	$2.0x10^{-6}$	$1.9x10^{-5}$	$1.6x10^{-5}$
463581	Carbonyl sulfide	$1.8x10^{-7}$	$1.7x10^{-6}$	$1.4x10^{-6}$
1330207	Xylene (mixed isomers)	$9.2x10^{-7}$	$8.6x10^{-6}$	$7.2x10^{-6}$
7440382	Arsenic	$3.7x10^{-11}$	$3.5x10^{-10}$	$2.9x10^{-10}$
7647010	Hydrochloric acid	$1.7x10^{-7}$	$1.6x10^{-6}$	$1.3x10^{-6}$
7664393	Hydrofluoric acid	$9.2x10^{-10}$	$8.6x10^{-9}$	$7.2x10^{-9}$
7782492	Selenium	$3.7x10^{-11}$	$3.5x10^{-10}$	$2.9x10^{-10}$

Table C-50 MACT II Emissions at AK Steel Ashland

Constituent	Emission Rate (g/s)						
	Battery Pushing		Quenching		Combustion stack		Pushing Control Device
	3	4	3	4	3	4	
Benzene soluble organics	$6.3x10^{-2}$	$9.8x10^{-2}$	$5.5x10^{-2}$	$8.3x10^{-2}$			
Benzo(a)pyrene	$3.2x10^{-5}$	$4.9x10^{-5}$	$2.7x10^{-5}$	$4.2x10^{-5}$	$1.8x10^{-6}$	$6.3x10^{-6}$	
Benzo(a)anthracene	$1.1x10^{-4}$	$1.7x10^{-4}$	$9.3x10^{-5}$	$1.4x10^{-4}$	$1.2x10^{-6}$	$4.3x10^{-6}$	$5.1x10^{-6}$
Benzene							$3.4x10^{-3}$
Acenaphthene	$8.2x10^{-5}$	$1.3x10^{-4}$	$7.1x10^{-5}$	$1.1x10^{-4}$	$2.6x10^{-6}$	$9.2x10^{-6}$	$6.5x10^{-5}$
Phenanthrene	$8.9x10^{-4}$	$1.4x10^{-3}$	$7.7x10^{-4}$	$1.2x10^{-3}$	$1.3x10^{-4}$	$4.5x10^{-4}$	$7.8x10^{-4}$
Fluorene	$1.2x10^{-4}$	$1.9x10^{-4}$	$1.0x10^{-4}$	$1.6x10^{-4}$	$9.8x10^{-6}$	$3.5x10^{-5}$	$1.8x10^{-4}$
Naphthalene	$2.1x10^{-3}$	$3.2x10^{-3}$	$1.8x10^{-3}$	$2.8x10^{-3}$	$1.2x10^{-3}$	$4.2x10^{-3}$	$2.2x10^{-3}$
2-Methylnaphthalene					$3.3x10^{-5}$	$1.2x10^{-4}$	$6.6x10^{-4}$
Anthracene	$9.5x10^{-5}$	$1.5x10^{-4}$	$8.2x10^{-5}$	$1.3x10^{-4}$	$7.2x10^{-7}$	$2.5x10^{-6}$	$9.0x10^{-5}$
Pyrene	$2.1x10^{-4}$	$3.2x10^{-4}$	$1.8x10^{-4}$	$2.8x10^{-4}$	$9.1x10^{-5}$	$3.2x10^{-4}$	$1.5x10^{-4}$
Benzo(e)pyrene					$6.7x10^{-6}$	$2.4x10^{-5}$	$1.2x10^{-6}$
Indeno(1,2,3-cd)pyrene	$6.3x10^{-5}$	$9.8x10^{-5}$	$5.5x10^{-5}$	$8.3x10^{-5}$			
Benzo(b)fluoranthene	$9.5x10^{-5}$	$1.5x10^{-4}$	$8.2x10^{-5}$	$1.3x10^{-4}$	$3.3x10^{-6}$	$1.2x10^{-5}$	$4.3x10^{-6}$
Fluoranthene	$3.0x10^{-4}$	$4.7x10^{-4}$	$2.6x10^{-4}$	$4.0x10^{-4}$	$8.6x10^{-5}$	$3.0x10^{-4}$	$9.0x10^{-5}$
Benzo(k)fluoranthene	$5.7x10^{-5}$	$8.8x10^{-5}$	$4.9x10^{-5}$	$7.5x10^{-5}$	$1.6x10^{-8}$	$5.3x10^{-8}$	$3.2x10^{-6}$
Acenaphthylene	$5.2x10^{-4}$	$8.0x10^{-4}$	$4.5x10^{-4}$	$6.8x10^{-4}$	$2.9x10^{-4}$	$1.0x10^{-3}$	$4.3x10^{-4}$
Chrysene	$1.8x10^{-4}$	$2.8x10^{-4}$	$1.6x10^{-4}$	$2.4x10^{-4}$	$4.8x10^{-6}$	$1.7x10^{-5}$	$1.4x10^{-5}$
Lead	$1.0x10^{-3}$	$1.6x10^{-3}$	$8.7x10^{-4}$	$1.3x10^{-3}$	$8.1x10^{-5}$	$2.9x10^{-4}$	$3.8x10^{-5}$
Manganese	$3.2x10^{-4}$	$5.0x10^{-4}$	$2.8x10^{-4}$	$4.3x10^{-4}$	$5.2x10^{-5}$	$1.9x10^{-4}$	$8.9x10^{-5}$
Nickel	$6.2x10^{-4}$	$9.6x10^{-4}$	$5.4x10^{-4}$	$8.2x10^{-4}$	$2.2x10^{-5}$	$7.3x10^{-5}$	$2.1x10^{-5}$
Antimony	$3.0x10^{-5}$	$4.6x10^{-5}$	$2.6x10^{-5}$	$3.9x10^{-5}$			
Arsenic	$6.3x10^{-4}$	$9.8x10^{-4}$	$5.5x10^{-4}$	$8.3x10^{-4}$	$4.7x10^{-5}$	$1.7x10^{-4}$	$8.6x10^{-6}$
Beryllium	$8.2x10^{-6}$	$1.3x10^{-5}$	$7.1x10^{-6}$	$1.1x10^{-5}$	$4.6x10^{-7}$	$1.6x10^{-6}$	$5.2x10^{-7}$
Cadmium	$3.4x10^{-5}$	$5.2x10^{-5}$	$2.9x10^{-5}$	$4.4x10^{-5}$	$4.3x10^{-6}$	$1.5x10^{-5}$	$1.9x10^{-6}$
Chromium	$1.0x10^{-4}$	$1.6x10^{-4}$	$8.7x10^{-5}$	$1.3x10^{-4}$	$8.1x10^{-5}$	$2.9x10^{-4}$	$6.1x10^{-5}$
Cobalt	$3.0x10^{-5}$	$4.6x10^{-5}$	$2.6x10^{-5}$	$3.9x10^{-5}$			
Phosphorus					$3.1x10^{-4}$	$1.1x10^{-3}$	$3.7x10^{-4}$
Selenium	$1.4x10^{-4}$	$2.2x10^{-4}$	$1.2x10^{-4}$	$1.8x10^{-4}$	$4.3x10^{-5}$	$1.5x10^{-4}$	$4.0x10^{-6}$

Table C-51 MACT II Emissions at AK Steel Middletown

Constituent	Emission Rate (g/s)			
	Battery Pushing	Quenching	Combustion Stack	Pushing Control Device 1,2,3[a]
Benzene soluble organics	7.2x10^{-2}	6.0x10^{-2}		
Benzo(a)pyrene	3.6x10^{-5}	3.0x10^{-5}	5.1x10^{-6}	
Benzo(a)anthracene	1.2x10^{-4}	1.0x10^{-4}	3.5x10^{-6}	7.5x10^{-7}
Benzene				4.9x10^{-4}
Acenaphthene	9.3x10^{-5}	7.9x10^{-5}	7.6x10^{-6}	9.5x10^{-6}
Phenanthrene	1.0x10^{-3}	8.5x10^{-4}	3.6x10^{-4}	1.2x10^{-4}
Fluorene	1.4x10^{-4}	1.1x10^{-4}	2.8x10^{-5}	2.6x10^{-5}
Naphthalene	2.4x10^{-3}	2.0x10^{-3}	3.4x10^{-3}	3.3x10^{-4}
2-Methylnaphthalene			9.6x10^{-5}	9.6x10^{-5}
Anthracene	1.1x10^{-4}	9.1x10^{-5}	2.1x10^{-6}	1.3x10^{-5}
Pyrene	2.4x10^{-4}	2.0x10^{-4}	2.6x10^{-4}	2.3x10^{-5}
Benzo(e)pyrene			1.9x10^{-5}	1.7x10^{-7}
Indeno(1,2,3-cd)pyrene	7.2x10^{-5}	6.0x10^{-5}		
Benzo(b)fluoranthene	1.1x10^{-4}	9.1x10^{-5}	9.6x10^{-6}	6.3x10^{-7}
Fluoranthene	3.5x10^{-4}	2.9x10^{-4}	2.5x10^{-4}	1.3x10^{-5}
Benzo(k)fluoranthene	6.5x10^{-5}	5.4x10^{-5}	4.5x10^{-8}	4.7x10^{-7}
Acenaphthylene	5.9x10^{-4}	5.0x10^{-4}	8.2x10^{-4}	6.3x10^{-5}
Chrysene	2.1x10^{-4}	1.8x10^{-4}	1.4x10^{-5}	2.0x10^{-6}
Lead	1.2x10^{-3}	9.7x10^{-4}	2.3x10^{-4}	5.5x10^{-6}
Manganese	3.7x10^{-4}	3.1x10^{-4}	1.5x10^{-4}	1.3x10^{-5}
Nickel	7.0x10^{-4}	5.9x10^{-4}	6.0x10^{-5}	3.0x10^{-6}
Antimony	3.4x10^{-5}	2.8x10^{-5}		
Arsenic	7.2x10^{-4}	6.0x10^{-4}	1.4x10^{-4}	1.3x10^{-6}
Beryllium	9.3x10^{-6}	7.9x10^{-6}	1.3x10^{-6}	7.7x10^{-8}
Cadmium	3.8x10^{-5}	3.2x10^{-5}	1.2x10^{-5}	2.8x10^{-7}
Chromium	1.2x10^{-4}	9.7x10^{-5}	2.3x10^{-4}	8.9x10^{-6}
Cobalt	3.4x10^{-5}	2.8x10^{-5}		
Phosphorus			8.9x10^{-4}	5.3x10^{-5}
Selenium	1.6x10^{-4}	1.3x10^{-4}	1.2x10^{-4}	5.9x10^{-7}

[a] The PCD (pushing control device) discharges through 3 stacks. Therefore, the emission rates in this table are from 1 stack. The total emissions from this PCD are derived from data in Table C-10.

Table C-52 MACT II Emissions at Erie Coke

Constituent	Emission Rate (g/s)					
	Battery Pushing		Quenching	Combustion stack	Pushing Control Device	
	A	B			A	B
Benzene soluble organics	$1.2x10^{-2}$	$1.7x10^{-2}$	$2.0x10^{-2}$			
Benzo(a)pyrene	$6.1x10^{-6}$	$8.6x10^{-6}$	$1.0x10^{-5}$	$1.3x10^{-6}$		
Benzo(a)anthracene	$2.0x10^{-5}$	$2.9x10^{-5}$	$3.4x10^{-5}$	$8.5x10^{-7}$	$3.5x10^{-7}$	$5.3x10^{-7}$
Benzene					$2.3x10^{-4}$	$3.5x10^{-4}$
Acenaphthene	$1.6x10^{-5}$	$2.2x10^{-5}$	$2.6x10^{-5}$	$1.8x10^{-6}$	$4.5x10^{-6}$	$6.8x10^{-6}$
Phenanthrene	$1.7x10^{-4}$	$2.4x10^{-4}$	$2.8x10^{-4}$	$8.8x10^{-5}$	$5.2x10^{-5}$	$8.6x10^{-5}$
Fluorene	$2.3x10^{-5}$	$3.3x10^{-5}$	$3.8x10^{-5}$	$6.8x10^{-6}$	$1.2x10^{-5}$	$1.9x10^{-5}$
Naphthalene	$4.0x10^{-4}$	$5.7x10^{-4}$	$6.6x10^{-4}$	$8.3x10^{-4}$	$1.4x10^{-4}$	$2.3x10^{-4}$
2-Methylnaphthalene				$2.3x10^{-5}$	$4.5x10^{-5}$	$6.8x10^{-5}$
Anthracene	$1.8x10^{-5}$	$2.6x10^{-5}$	$3.0x10^{-5}$	$5.0x10^{-7}$	$6.0x10^{-6}$	$9.2x10^{-6}$
Pyrene	$4.0x10^{-5}$	$5.7x10^{-5}$	$6.6x10^{-5}$	$6.3x10^{-5}$	$1.0x10^{-5}$	$1.6x10^{-5}$
Benzo(e)pyrene				$4.7x10^{-6}$	$8.6x10^{-8}$	$1.2x10^{-7}$
Indeno(1,2,3-cd)pyrene	$1.2x10^{-5}$	$1.7x10^{-5}$	$2.0x10^{-5}$			
Benzo(b)fluoranthene	$1.8x10^{-5}$	$2.6x10^{-5}$	$3.0x10^{-5}$	$2.3x10^{-6}$	$2.9x10^{-7}$	$4.5x10^{-7}$
Fluoranthene	$5.9x10^{-5}$	$8.3x10^{-5}$	$9.7x10^{-5}$	$6.0x10^{-5}$	$6.0x10^{-6}$	$9.2x10^{-6}$
Benzo(k)fluoranthene	$1.1x10^{-5}$	$1.6x10^{-5}$	$1.8x10^{-5}$	$1.0x10^{-8}$	$2.2x10^{-7}$	$3.3x10^{-7}$
Acenaphthylene	$1.0x10^{-4}$	$1.4x10^{-4}$	$1.7x10^{-4}$	$2.0x10^{-4}$	$2.9x10^{-5}$	$4.5x10^{-5}$
Chrysene	$3.5x10^{-5}$	$5.0x10^{-5}$	$5.8x10^{-5}$	$3.3x10^{-6}$	$9.3x10^{-7}$	$1.4x10^{-6}$
Lead	$2.0x10^{-4}$	$2.8x10^{-4}$	$3.2x10^{-4}$	$5.6x10^{-5}$	$2.6x10^{-6}$	$3.9x10^{-6}$
Manganese	$6.2x10^{-5}$	$8.8x10^{-5}$	$1.0x10^{-4}$	$3.7x10^{-5}$	$6.0x10^{-6}$	$9.1x10^{-6}$
Nickel	$1.2x10^{-4}$	$1.7x10^{-4}$	$2.0x10^{-4}$	$1.4x10^{-5}$	$1.4x10^{-6}$	$2.2x10^{-6}$
Antimony	$5.7x10^{-6}$	$8.1x10^{-6}$	$9.5x10^{-6}$			
Arsenic	$1.2x10^{-4}$	$1.7x10^{-4}$	$2.0x10^{-4}$	$3.3x10^{-5}$	$5.8x10^{-7}$	$8.8x10^{-7}$
Beryllium	$1.6x10^{-6}$	$2.2x10^{-6}$	$2.6x10^{-6}$	$3.2x10^{-7}$	$2.9x10^{-8}$	$5.8x10^{-8}$
Cadmium	$6.4x10^{-6}$	$9.1x10^{-6}$	$1.1x10^{-5}$	$3.0x10^{-6}$	$1.3x10^{-7}$	$2.0x10^{-7}$
Chromium	$2.0x10^{-5}$	$2.8x10^{-5}$	$3.2x10^{-5}$	$5.6x10^{-5}$	$4.2x10^{-6}$	$6.3x10^{-6}$
Cobalt	$5.7x10^{-6}$	$8.1x10^{-6}$	$9.5x10^{-6}$			
Phosphorus				$2.2x10^{-4}$	$2.6x10^{-5}$	$3.9x10^{-5}$
Selenium	$2.7x10^{-5}$	$3.8x10^{-5}$	$4.4x10^{-5}$	$3.0x10^{-5}$	$2.7x10^{-7}$	$4.2x10^{-7}$

Table C-53 MACT II Emissions at Tonawanda

Constituent	Emission Rate (g/s)		
	Battery Pushing	Quenching	Combustion Stack
Benzene soluble organics	$5.8x10^{-2}$	$2.9x10^{-2}$	
Benzo(a)pyrene	$2.9x10^{-5}$	$1.4x10^{-5}$	$3.2x10^{-6}$
Benzo(a)anthracene	$9.8x10^{-5}$	$4.9x10^{-5}$	$2.2x10^{-6}$
Acenaphthene	$7.5x10^{-5}$	$3.7x10^{-5}$	$4.7x10^{-6}$
Phenanthrene	$8.1x10^{-4}$	$4.0x10^{-4}$	$2.3x10^{-4}$
Fluorene	$1.1x10^{-4}$	$5.5x10^{-5}$	$1.8x10^{-5}$
Naphthalene	$1.9x10^{-3}$	$9.5x10^{-4}$	$2.1x10^{-3}$
2-Methylnaphthalene			$6.0x10^{-5}$
Anthracene	$8.6x10^{-5}$	$4.3x10^{-5}$	$1.3x10^{-6}$
Pyrene	$1.9x10^{-4}$	$9.5x10^{-5}$	$1.6x10^{-4}$
Benzo(e)pyrene			$1.2x10^{-5}$
Indeno(1,2,3-cd)pyrene	$5.8x10^{-5}$	$2.9x10^{-5}$	
Benzo(b)fluoranthene	$8.6x10^{-5}$	$4.3x10^{-5}$	$6.0x10^{-6}$
Fluoranthene	$2.8x10^{-4}$	$1.4x10^{-4}$	$1.5x10^{-4}$
Benzo(k)fluoranthene	$5.2x10^{-5}$	$2.6x10^{-5}$	$2.7x10^{-8}$
Acenaphthylene	$4.7x10^{-4}$	$2.4x10^{-4}$	$5.1x10^{-4}$
Chrysene	$1.7x10^{-4}$	$8.3x10^{-5}$	$8.5x10^{-6}$
Lead	$9.2x10^{-4}$	$4.6x10^{-4}$	$1.5x10^{-4}$
Manganese	$2.9x10^{-4}$	$1.5x10^{-4}$	$9.3x10^{-5}$
Nickel	$5.6x10^{-4}$	$2.8x10^{-4}$	$3.7x10^{-5}$
Antimony	$2.7x10^{-5}$	$1.4x10^{-5}$	
Arsenic	$5.8x10^{-4}$	$2.9x10^{-4}$	$8.5x10^{-5}$
Beryllium	$7.5x10^{-6}$	$3.7x10^{-6}$	$8.1x10^{-7}$
Cadmium	$3.0x10^{-5}$	$1.5x10^{-5}$	$7.7x10^{-6}$
Chromium	$9.2x10^{-5}$	$4.6x10^{-5}$	$1.5x10^{-4}$
Cobalt	$2.7x10^{-5}$	$1.4x10^{-5}$	
Phosphorus			$5.6x10^{-4}$
Selenium	$1.3x10^{-4}$	$6.3x10^{-5}$	$7.6x10^{-5}$

Table C-54 By-Product Plant Emission Rates at AK Steel Middletown

Source Name	Emission Rate (g/s)		
	Benzene	Toluene	Xylene (mixed isomers)
BPP1 Tar decanter	$1.3x10^{-2}$	$8.0x10^{-4}$	$4.0x10^{-4}$
BPP2 Tar intercepting sump	$2.3x10^{-3}$	$1.4x10^{-4}$	$6.9x10^{-5}$
BPP3 Tar dewatering tank	$5.1x10^{-3}$	$3.1x10^{-4}$	$1.5x10^{-4}$
BPP4 Tar storage tank	$4.6x10^{-3}$	$2.8x10^{-4}$	$1.4x10^{-4}$
BPP5 Flushing liquor circulation tank	$3.2x10^{-3}$	$1.9x10^{-4}$	$9.5x10^{-5}$
BPP6 Excess ammonia liquor tank	$3.5x10^{-4}$	$2.1x10^{-5}$	$1.0x10^{-5}$
BPP7 Wash oil decanter	$9.1x10^{-4}$	$5.4x10^{-5}$	$2.7x10^{-5}$
BPP8 Tank truck loading - tar	$1.4x10^{-2}$	$8.1x10^{-4}$	$4.1x10^{-4}$
BPP9 Fugitive emissions - wastewater	$1.0x10^{-2}$	$6.3x10^{-4}$	$3.1x10^{-4}$
Total Emission Rate by Chemical	$5.4x10^{-2}$	$3.2x10^{-3}$	$1.6x10^{-3}$

Table C-55 By-Product Plant Emission Rates at AK Steel Ashland

Source Name	Emission Rate (g/s)		
	Benzene	Toluene	Xylene (mixed isomers)
BPP1 Light oils storage tank	$3.3x10^{-3}$	$2.0x10^{-4}$	$1.0x10^{-4}$
BPP2 Tar decanter	$3.1x10^{-2}$	$1.8x10^{-3}$	$9.2x10^{-4}$
BPP3 Tar intercepting sump	$5.3x10^{-3}$	$3.2x10^{-4}$	$1.6x10^{-4}$
BPP4 Tar dewatering tank	$1.2x10^{-2}$	$7.0x10^{-4}$	$3.5x10^{-4}$
BPP5 Tar storage tank	$1.1x10^{-2}$	$6.3x10^{-4}$	$3.2x10^{-4}$
BPP6 Light oil condenser vent	$5.0x10^{-2}$	$3.0x10^{-3}$	$1.5x10^{-3}$
BPP7 Light oil sump	$8.3x10^{-3}$	$5.0x10^{-4}$	$2.5x10^{-4}$
BPP8 Flushing liquor circulation tank	$7.2x10^{-3}$	$4.3x10^{-4}$	$2.2x10^{-4}$
BPP9 Excess ammonia liquor tank	$7.8x10^{-4}$	$4.7x10^{-5}$	$2.3x10^{-5}$
BPP10 Wash oil decanter	$2.1x10^{-3}$	$1.3x10^{-4}$	$6.3x10^{-5}$
BPP11 Wash oil circulation tank	$2.1x10^{-3}$	$1.3x10^{-4}$	$6.3x10^{-5}$
BPP12 Tank truck loading -light oil	$8.1x10^{-2}$	$4.8x10^{-3}$	$2.4x10^{-3}$
BPP13 Tank truck loading - tar	$7.8x10^{-3}$	$4.7x10^{-4}$	$2.3x10^{-4}$
BPP14 Fugitive emission - wastewater	$1.3x10^{-2}$	$7.8x10^{-4}$	$3.9x10^{-4}$
BPP15 Fugitive equipment leaks - light oil plant	$4.3x10^{-2}$	$2.6x10^{-3}$	$1.3x10^{-3}$
Total Emission Rate by Chemical	$2.8x10^{-1}$	$1.7x10^{-2}$	$8.3x10^{-3}$

Table C-56 By-Product Plant Emission Rates at Erie Coke

Source Name	Emission Rate (g/s)		
	Benzene	Toluene	Xylene (mixed isomers)
BPP1 Excess ammonia liquor tank[a]	3.5×10^{-3}	2.1×10^{-4}	1.1×10^{-4}
BPP2 Excess ammonia liquor tank	1.2×10^{-3}	7.1×10^{-5}	3.5×10^{-5}
BPP3 Tank truck loading - tar	1.7×10^{-3}	1.0×10^{-4}	5.2×10^{-5}
BPP4 Fugitive emissions - wastewater	1.7×10^{-3}	1.0×10^{-4}	5.2×10^{-5}
Total Emission Rate by Chemical	8.2×10^{-3}	4.9×10^{-4}	2.5×10^{-4}

[a] This facility has two ammonia tanks. Their dimensions are provided in Table F-3

Table C-57 By-Product Plant Emission Rates at Tonawanda

Source Name	Emission Rate (g/s)		
	Benzene	Toluene	Xylene (mixed isomers)
BPP1 Light oil storage tank	2.0×10^{-2}	1.2×10^{-3}	5.9×10^{-4}
BPP2 Excess ammonia liquor tank	6.3×10^{-3}	3.8×10^{-4}	1.9×10^{-4}
BPP3 Ammonia still building	4.0×10^{-2}	2.4×10^{-3}	1.2×10^{-3}
BPP4 Tank truck loading- light oil	1.2×10^{-2}	7.2×10^{-4}	3.6×10^{-4}
BPP5 Tank truck loading - tar	1.7×10^{-3}	1.0×10^{-4}	5.2×10^{-5}
BPP6 Fugitive emissions - wastewater	7.3×10^{-3}	4.4×10^{-4}	2.2×10^{-4}
BPP7 Fugitive equipment leaks - light oil plant	9.3×10^{-2}	5.6×10^{-3}	2.8×10^{-3}
Total Emission Rate by Chemical	1.8×10^{-1}	1.1×10^{-2}	5.4×10^{-3}

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Appendix C-1: Emission Factors for By-Product Recovery Processes

Table C-58. Coke By-Product Plant Emission Factors[a] for Benzene and BTX [b]

Type of by-product plant operation	Control device	Benzene				BTX			
		Furnace plant		Foundry plant		Furnace plant		Foundry plant	
		kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Light-oil storage tank[c]	Uncontrolled	0.0058	0.0116	0.0031	0.0062	0.0083	0.0166	0.0049	0.0098
	Gas blanketing	0.00012	0.00024	0.00006	0.00012	0.00017	0.00034	0.000094	0.000188
Tar decanter	Uncontrolled	0.054[d]	0.108[d]	0.025	0.050	0.077	0.154	0.039	0.078
	Gas blanketing	0.0011[d]	0.0022[d]	0.0005	0.0010	0.0016	0.0032	0.00079	0.00158
Naphthalene separation and processing	Uncontrolled	0.11	0.22	0.08	0.16	0.16	0.32	0.13	0.26
	Activated carbon	0.00035	0.00070	0.00025	0.00050	0.00050	0.0010	0.00039	0.00078
Cooling tower	Direct-water, uncontrolled	0.27	0.54	0.20	0.40	0.69	1.38	0.61	1.22
	Tar-bottom, uncontrolled	0.070	0.14	0.051	0.102	0.10	0.20	0.080	0.16
Tar intercepting sump	Uncontrolled	0.0095	0.019	0.0045	0.0090	0.014	0.028	0.0071	0.014
Tar dewatering tank	Uncontrolled	0.021[e]	0.042[e]	0.0099	0.0198	0.030	0.060	0.016	0.032
	Gas blanketing	0.00045	0.00084	0.00020	0.00040	0.00060	0.0012	0.00031	0.00062
Tar storage tank	Uncontrolled	0.0066[e]	0.0132[e]	0.0031	0.0062	0.0094	0.0188	0.0049	0.0098
	Gas blanketing	0.00038	0.00076	0.00018	0.00036	0.00054	0.00108	0.00028	0.00056
Light-oil condenser vent	Uncontrolled	0.089	0.178	0.048	0.096	0.13	0.26	0.076	0.152
	Gas blanketing	0.0018	0.0036	0.00097	0.00194	0.0026	0.0052	0.0015	0.0030
Light-oil sump	Uncontrolled	0.015[e]	0.030[e]	0.0081	0.0162	0.021	0.042	0.013	0.026
	Gas blanketing	0.00030	0.00060	0.00016	0.00032	0.00043	0.00086	0.0025	0.0050
BTX storage[c]	Uncontrolled	0.0058	0.0116	0.0031	0.0062	0.0083	0.0166	0.0049	0.0098
	Gas blanketing	0.00012	0.00024	0.000060	0.00012	0.00017	0.00034	0.000094	0.000188

Table C-58. Coke By-Product Plant Emission Factors[a] for Benzene and BTX [b]

Type of by-product plant operation	Control device	Benzene				BTX			
		Furnace plant		Foundry plant		Furnace plant		Foundry plant	
		kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Benzene storage[c]	Uncontrolled	0.0058	0.0116	0.0031	0.0062	0.0058	0.0116	0.0031	0.0062
	Gas blanketing	0.00012	0.00024	0.00006	0.00012	0.00012	0.00024	0.00006	0.00012
Flushing liquor circulation tank	Uncontrolled	0.013[d]	0.026[d]	0.0095	0.019	0.019	0.038	0.015	0.030
	Gas blanketing	0.00026	0.00052	0.00019	0.00038	0.00037	0.00074	0.00030	0.00060
Excess-ammonia liquor tank	Uncontrolled	0.0014	0.0028	0.0010	0.0020	0.0020	0.0040	0.0016	0.0032
	Gas blanketing	0.000028	0.000056	0.000020	0.000040	0.000040	0.00008	0.000031	0.000062
Wash-oil decanter	Uncontrolled	0.0038	0.0076	0.0021	0.0042	0.0054	0.0108	0.0033	0.0066
	Gas blanketing	0.000076	0.00015	0.000041	0.000082	0.00011	0.00022	0.000065	0.00013
Wash-oil circulation tank	Uncontrolled	0.0038	0.0076	0.0021	0.0042	0.0054	0.0108	0.0033	0.0066
	Gas blanketing	0.000076	0.00015	0.000041	0.000082	0.00011	0.00022	0.000065	0.00013

[a] Emission Factor Rating: E, Except as Noted

[b] Emission factor units are kg/Mg and lb/ton of coke pushed. BTX = benzene, toluene and xylene. The emission factors for BTX are estimated from equations given in the text. Uncontrolled emission factors represent pre–by-product plant pre-NESHAP control levels; controlled emission factors represent post-NESHAP control levels. No emissions are allowed from naphthalene processing.

[c] The reader may also use EPA's TANKS program to estimate emissions from this source. The program is available in electronic form through EPA’s Technology Transfer Network. For information call (919) 541-5285.

[d] The benzene emission factor rating for this furnace plant operation is D.

[e] The benzene emission factor rating for this furnace plant operation is B.

Appendix D: Air Dispersion Modeling

Introduction

Dispersion modeling of coke oven facility emissions is central to determining the ambient air concentrations, deposition rates, and the resulting population exposure and risk. For this risk assessment, an atmospheric dispersion modeling approach was required to estimate both atmospheric concentrations and surface deposition rates of vapor-phase and particulate air pollutants from coke oven facilities. Emissions from coke oven batteries, combustion stacks, quench towers, pushing operations and pushing emission control devices, and By-product recovery plants are included in this analysis.

Because of the relatively, large, rectangular shape of a typical coke oven battery and the large quantities of heat associated with several of the operations at coke oven facilities, standard regulatory dispersion models are unable to realistically simulate the enhanced plume rise associated with these uniquely shaped sources and their highly buoyant emissions. To better simulate emissions from these sources, emissions were modeled with a two step process; first to determine the plume height and second to simulate the dispersion, transport and deposition of the pollutant. All other emissions were modeled with a standard version of an EPA regulatory model.

Emission Characterization

The emission sources included in the risk assessment for each of the facilities modeled are listed in Table D-1. Emissions were characterized from five major source types: A) coke oven battery, B) combustion stack, C) quench tower, D) pushing fugitives and control device, and E) the By-product recovery plant. An extensive data collection effort was conducted for each emission source. A listing of source-specific parameters utilized in the model assessment for each site are include in Appendix F.

Table D-1. Emission Sources Included in Each Coke Oven Residual Risk Assessment

Emission Point	AK Steel Middletown	AK Steel Ashland	Tonawanda	Erie Coke
(A) Coke Oven Battery (Charging, Doors, Lids, Offtakes)	✓	✓	✓	✓
(B) Combustion stack	✓	✓	✓	✓
(C) Quench Tower	✓	✓	✓	✓
(D) Pushing Emissions:				
: Fugitive	✓	✓	✓	✓
Control Device	✓	✓		
(E) By-Product Plant:				
Light Oil Storage Tank		✓	✓	
Tar Decanter	✓	✓		
Tar Intercepting Sump	✓	✓		
Tar Dewatering Tank	✓	✓		
Tar Storage Tank	✓	✓		
Light Oil Condenser Vent		✓		
Light Oil Sump		✓		
Flushing Liquor Circulation Tank	✓	✓		
Excess Ammonia Liquor Tank	✓	✓	✓	✓
Wash Oil Decanter	✓	✓		
Wash Oil Circulation Tank		✓		
Ammonia Still Building			✓	
Tank Truck Loading-light Oil		✓	✓	
Tank Truck Loading-tar	✓	✓	✓	✓
Fugitive Emissions from Wastewater	✓	✓	✓	✓
Fugitive Equipment Leaks-light Oil Plant		✓	✓	

Dispersion Modeling Approach

The assessment utilized a refined dispersion model to predict facility impacts at off-site locations. Emissions were modeled using a unit emission rate of 1g/s. The outputs of this modeling were used to estimate ambient concentrations (Table D-2 provides an example output. In this case, it is the location of the maximum concentration). The unit air concentration estimated was multiplied by the emission rate for each HAP (Tables C-26 to C-57) to yield the estimated ambient air concentration for each

HAP/source. The modeling analysis also included the use of a representative historical meteorological data set for each site, as well as a dense receptor grid. As noted above, because of the unique shape of the battery and the large quantities of heat associated with several of the operations at coke oven facilities, standard regulatory dispersion models are unable to realistically simulate the "enhanced plume rise" associated with several emissions.

Table D-2 . Maximized Unitized Air Concentrations

Facility	Source Dispersion ID[1]	χ/Qv [2] (ug-s/g-m^3)	χ/Qp [3] (ug-s/g-m^3)	X[4] (m)	Y[4] (m)	Distance (m)[5]
AK Steel Ashland	BAT3	3.1	3.1	-321.4	383	500
	BAT4	3.5	3.5	-346.4	200	400
	BPP	234.0	0.0	104.2	591	600
	COM3	1.2	1.2	-459.6	385.7	600
	COM4	0.2	0.2	1378.9	1157	1800
	PCD	6.3	6.3	-306.4	257.1	400
	QCT3	1.3	1.3	-519.6	300	600
	QCT4	2.2	2.2	-385.7	459.6	600
AK Steel Middletown	BAT	0.5	0.5	-104.7	590.9	600
	BPP	36.5	0	-1127.6	-410.4	1200
	COM	0.04	0.04	1750	3031.1	3500
	PCD1	0.8	0.8	0.0	600	600
	PCD2	0.8	0.8	0.0	600	600
	PCD3	0.7	0.7	-615.6	-1691.5	1800
	QCT	0.1	0.1	1250	2165.1	2500
Erie Coke	BAT-A	3.0	3.0	433.0	-250	500
	BAT-B	2.4	2.4	433.0	-250	500
	BPP	110.9	0.0	187.9	68.4	200
	COM	0.1	0.1	1212.4	-700	1400
	QCT	0.4	0.4	433.0	-250	500
Tonawanda	BAT-2	1.5	1.5	321.4	383.0	500
	BPP	35.1	0.0	-229.8	192.8	300
	COM	0.1	0.1	2165.1	1250	2500
	QCT	0.3	0.3	1212.4	700	1400

[1] BAT = Battery; BPP = By-Product Plant; COM = Combustion Stack; PCD = Pushing Control Device; QCT = Quenching,

[2 & 3] χ= concentration in μg/ m3 : Q = emission rate in grams/second: v = vapor: p = particulate

[4] Coordinates of maximum concentration; zero at approximate center of facility

[5] Distance of maximum concentration from zero

These sources include the coke oven battery emissions (charging, doors, lids, offtake leaks) and the fugitive emissions from pushing operations. Figure D-1 depicts the emission sources included in the enhanced plume rise analysis.

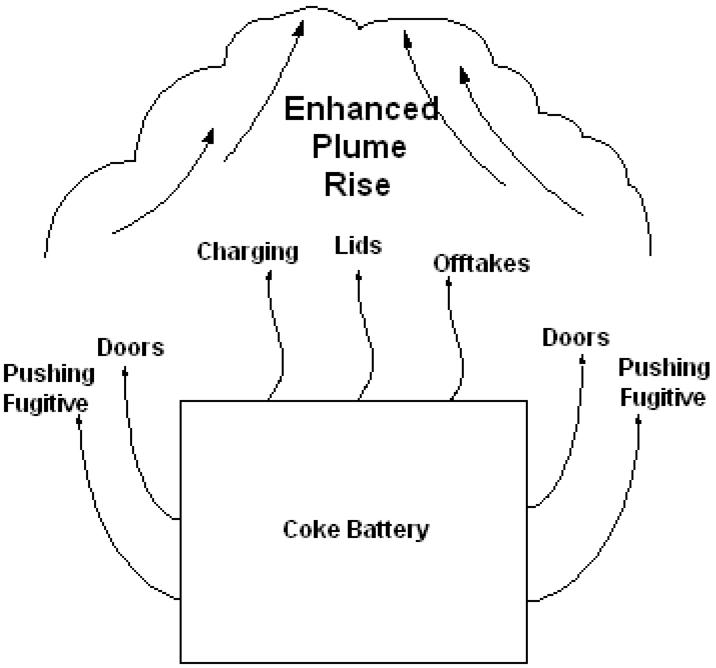

Figure D-1. Enhanced Plume Rise Sources

To simulate the “enhanced plume rise”, these sources were first modeled with the Buoyant Line Plume (BLP) Model to determine the plume height and then modeled with EPA’s Industrial Source Complex Short Term-3 (ISCST3) to simulate the subsequent dispersion and transport of the pollutant. All other emissions (By-product recovery plant, combustion stack, quench tower, and pushing control device) were modeled with the standard version of ISCST3, (i.e., they were not modeled first with the BLP model). To incorporate the “enhanced plume rise”, a modified version of the ISCST3 model was employed for several sources. These modifications are discussed further below.

BLP is a steady-state gaussian plume dispersion model that was developed to simulate dispersion from a buoyant line source (ERT, 1980). ISCST3 is a steady-state gaussian plume dispersion model capable of assessing pollutant concentrations and deposition flux (resulting from dry or wet processes) for nonreactive pollutants in both flat and complex terrain from a variety of source configurations (U.S. EPA, 1995). The ISCST3 and BLP modeling options are presented in Table D-3. Source parameters used in ISCST3 and BLP modeling are provided in Appendix F.

Table D-3. ISCST3 and BLP Model* Options for Coke Oven Modeling

Modeling Option	Selected Parameter
Type of calculations	ISCST3 - Annual avg. concentration, dry and wet deposition
Source type	ISCST3 - Point, area, volume BLP - Line
Receptor orientation	ISCST3 - Polar with actual terrain elevations BLP - Discrete with flat terrain
Terrain characterization	Non-complex within 2km of all sites
Dispersion coefficient	Rural for both models
Regulatory default	ISCST3 - Yes (except as noted for enhanced plume rise sources)
Building downwash	BLP - Included in plume rise calculation for enhanced plume rise sources
Buoyancy induced dispersion	ISCST3 - Not included for enhanced plume rise sources BLP - Not applicable
Stack tip downwash	ISCST3 - Not included for enhanced plume rise sources BLP - Not applicable
Plume deposition depletion	ISCST3 - Not included BLP - Not applicable
Meteorology	5 years representative NWS

* ISC Model version No. 99155 (standard and modified) and BLP Model Version No. 90081

Enhanced Plume Rise Modeling

BLP Plume Rise Calculations

Coke oven facilities produce significant heat from large, parallel oven batteries, which behave as low-level buoyant line sources. Because of the parallel-line source configuration, plume rise is “enhanced” as ambient air is not fully entrained into the plume. The EPA’s Buoyant Line Plume (BLP) model (U.S. EPA, 1980) has been specifically developed to simulate the plume rise from multiple buoyant line sources that are subject to downwash. As such, the plume rise associated with coke oven batteries and pushing fugitive emissions are were modeled using the BLP model. Line source dimensions for BLP modeling were developed from the physical size of the battery structure. To simulate the potential for plume downwash in the wake of the battery structure, the BLP model option to include building downwash was employed in the calculations. Representative dimensions and orientation for battery at each site are presented in Appendix E.

The buoyancy flux is an important component in the BLP model in determining plume rise. Buoyancy flux from both convective heat transfer and fugitive emissions was calculated using the approach outlined in a study performed by Sciences International (2000) for the Coke Oven Environmental Task Force (COETF). A discussion of this approach and calculations are presented in Appendix E. Estimates of the predicted plume rise for each facility are presented in Table D-4. Typical enhanced plume rise estimates of 30 to 60 meters were estimated for each battery.

Table D-4 Summary Statistics for Plume Rise Data

Facility	Maximum Hourly Plume Rise (m)	Median Hourly Plume Rise (m)	Minimum Hourly Plume Rise (m)	Mode of Hourly Plume Rise (m)	90th Percentile of Hourly Plume Rise (m)	10th Percentile of Hourly Plume Rise (m)	Average
AK Steel–Middletown	218.3	36.1	9.0	Between 30 and 40	67.6	23.0	42.7
AK Steel–Ashland	348.9	60.3	18.8	Between 40 and 50	114.4	40.7	70.9
Erie Coke	183.8	28.5	9.3	Between 20 and 30	46.6	17.5	31
Tonawanda Coke	229.3	34.7	8.8	Between 30 and 40	62.2	20.9	39.5

Modified ISCST3 Calculations

The ISCST3 model, for this portion of the assessment, was modified to bypass plume rise calculations and accept a user provided final plume rise (from the BLP calculations). The ISCST3 model provides the option of specifying a variable emission rate for individual sources or for groups of sources. The hourly emission file includes emission rate, stack gas exit temperature, and exit velocity, but does not include a variable for physical stack height. For the coke oven risk assessment, the ISCST3 model was modified to include physical stack height in the emission file. Then, the final hourly plume height (which includes the physical battery height plus the enhanced plume rise) from the BLP model was input as the physical stack height for every hour.

To account for the relatively large physical size of the coke oven battery itself and to better approximate downwind transport and plume growth, the emissions were spread out over a wide horizontal area. This was accomplished by simulating the initial plume with a series of “representative” sources. Each coke oven battery was partitioned into a set of 14 equal rectangular areas (two rows of seven). To approximate the emissions from these rectangular areas, each shape (one-fourteenth of the total area of the battery) is represented in ISCST3 as a circular stack with a stack diameter equal to the effective area of the rectangle. Each circular stack is modeled by ISCST3 at the center of its corresponding rectangular area. This “representative” point source approach creates an initial plume horizontal width equal to approximately the physical size of the battery. The number of representative stacks used to simulate the batteries was determined based on a sensitivity analysis described in Appendix E. Figure D-2 depicts the “representative” stack configuration for a typical battery.

The final hourly plume height which includes the physical battery height plus the enhanced plume rise from the BLP model, was input as the physical stack height to ISCST3 (the model code was modified to accept this hourly value). This value was allowed to vary hourly with the changes in the meteorological conditions (as simulated in BLP). As the above representation is believed to be a reasonable approximation of the buoyant battery plume, no further dispersion enhancements (i.e., BID, stack-tip downwash, gradual plume rise), were include in the ISCST3 modeling. A sensitivity evaluation of these”enhancement” features show such features will have a minimal effect on the predicted ambient concentration and depositions at critical off site locations. In summary these evaluations show:

- gradual plume rise was not considered (i.e., the final plume height is assumed directly above the battery). Under most meteorological conditions, final plume rise is reached before the plume reaches the facility fenceline;
- under “typical conditions”, buoyancy induced dispersion (BID) will result in an increase of plume size by about 5% (see Appendix E);
- the difference in ambient predictions resulting from different plume downwash calculations (i.e., between the BLP algorithm and newer ISCST3 algorithms) is minimal at offsite locations;
- increasing the number of “representative stacks from 14 to 36 results in ambient predictions that vary by less than 10% (see Appendix E).

Standard ISCST3 Modeling

Emissions not associated with the buoyant battery plume were modeled with a “standard” version of the ISCST3 model. This include emissions from the By-product recovery plant, combustion stack, quench tower, and pushing control device. Emissions from the combustion stack, quench tower, and pushing control device were represented as a point source in the ISCST3 model. The By-product recovery plant was modeled as a series of volume and area sources to represent the different operations at the plant.

Receptor Data

The geographic centroid of each coke oven facility was used as the origin of the model domain. ISCST3 output is provided on a polar grid with 36 radii and 32 concentric circles starting at 100 m and spaced every 100 m out to 600 m, every 200 m out to 2,000 m, every 500 m out to 5,000 m, every 1,000 m out to 10,000 m, and finally every 5,000 m out to 50,000 m (50 km). Those receptors located within a facility’s actual fence line were not used in the analysis.

Receptor elevations for the radial array were selected based on the maximum elevation in the areas that each receptor represents (the area ± 5 degrees radially and one-half of the distance to the adjacent receptor rings). The ISCST3 model is generally considered to be conservative (i.e., it may over predict in areas of complex terrain (terrain above stack height)), and, therefore, should not be used under such conditions in a regulatory application. The Middletown, Erie, and Tonawanda sites are in relatively flat terrain. The Ashland site can be characterized by some complex terrain within several kilometers of the site. However, for all the sites assessed, critical receptors are in areas that are not characterized as complex terrain.

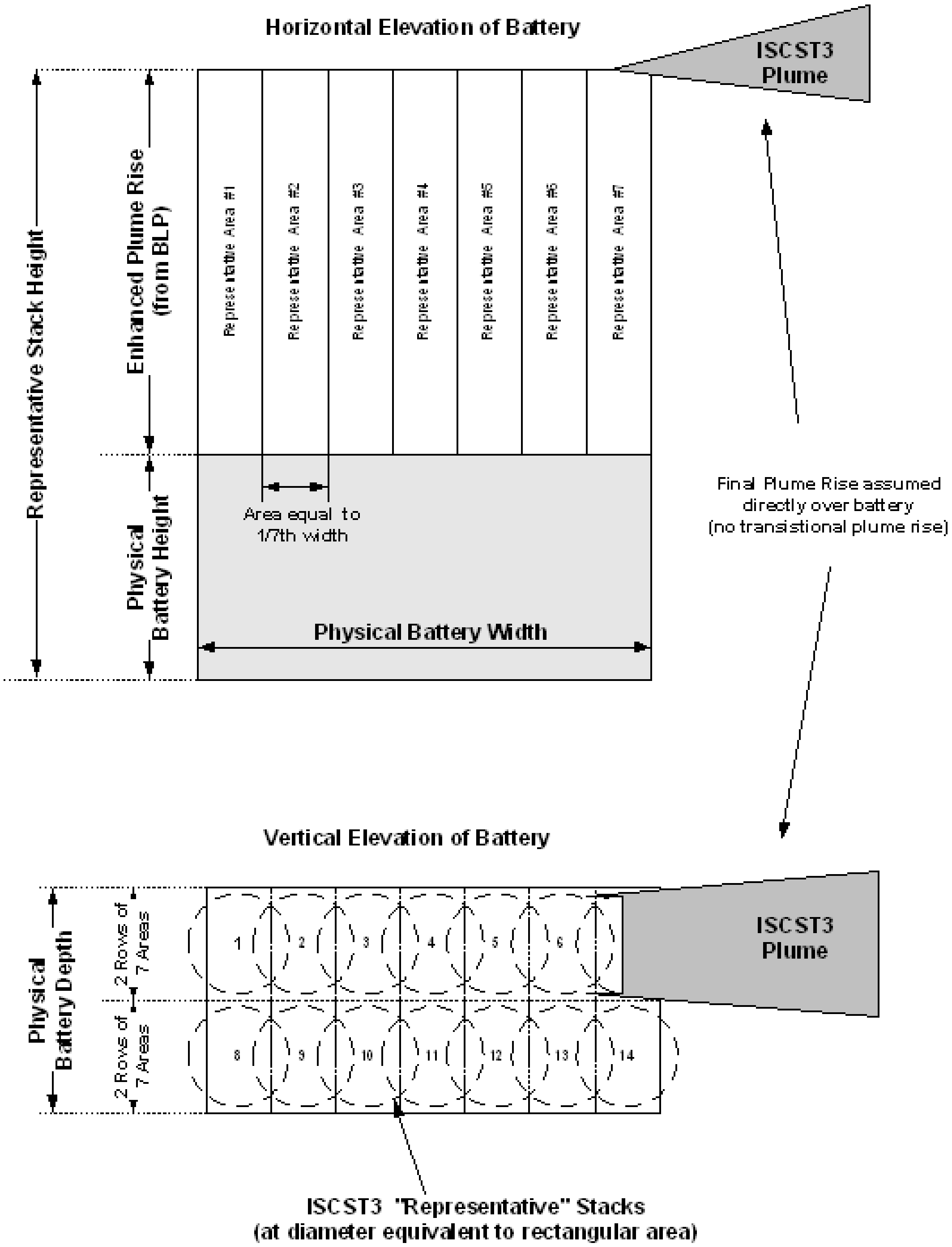

Figure D-2. ISCST3 Plume Representation for Buoyant Coke Sources

Meteorology

Each coke oven facility is modeled with hourly representative meteorological data. Five years of representative meteorological data consisting of surface observations and coincident mixing height data were used in this analysis. Surface data were collected from Solar and Meteorological Surface Observation Network (SAMSON) CD-ROMs (U.S. Department of Commerce [DOC] and U.S. Department of Energy [DOE], 1993). Mixing height data were downloaded from EPA Support Center for Regulatory Air Models (SCRAM) air dispersion modeling site (http://www.epa.gov/scram001/). Table D-5 identifies the representative meteorological data used in modeling for each facility. All meteorological data was processed into ISCST3 ready format with the EPA meteorological preprocessor program PCRAMMET (Version: 98181).

Land-use-based parameters for preprocessing the meteorological data were based on Geographic Information Retrieval Analysis System (GIRAS) data. The digital coverages of the GIRAS data are available from U.S. EPA (1994) by 1-degree quadrangle (1:250,000 scale).

Table D-5. Meteorological Data Sources

Facility	Year	Surface Station	Upper-Air-Site
Ak Steel-Middletown	1986-1990	Dayton, OH (93815)	Wright Paterson AFB, OH (13840)
Ak Steel-Ashland	1985-1988, 1990	Huntington, WV (03860)	Huntington, WV (03860)
Erie Coke	1985-1986, 1988-1990	Erie, PA (14860)	Buffalo, NY (14733)
Tonawanda	1985-1986, 1988-1990	Buffalo, NY (14733)	Buffalo, NY (14733)

Input values/assumptions used in ISCST3 modeling include:

Site-specific surface roughness (0.1 for each site)

Friction velocity, u=ku /ln (z/zo), where k is von Karman constant of 0.4

No precipitation

Monin-Obukhov length as a function of surface roughness and stability class as defined by Golder (1972)

State of Vegetation – Unstressed and Active

Default values for gases in vegetation/land: cuticle resistance, ground resistance and reference resistance of pollutant to reactivity through leaf – expressed in terms of SO2: cuticle resistance 30 s/cm, ground resistance = 10 s/cm, pollutant reference reactivity = 8.

Incoming solar radiation: based on scheme implemented in MPRM (Irwin et al., 1988) - per Table 5-2.3

Leaf Area Index – ratio of leaf surface area divided by ground surface area; 0.2 based on a urban or built-up area

Confidence in Dispersion Modeling Results

When reviewing the results of this assessment, it is important to note that any dispersion modeling assessment involves a series of “trade-offs” between the actual physical characteristics of the source and how they are numerically represented. Generally, these “trade-offs” are made to balance available model input data as well as known model strengths and weaknesses with the level of accuracy/uncertainty that is required in the assessment. When applying a model in a regulatory (or rulemaking) setting, the modeler will generally make these “trade-offs” to provide a “conservative prediction”, (i.e., one that is public health protective) yet provides results that are realistic enough as to not place an undue regulatory burden on the affected sources. In past assessments of coke oven facilities, the complex plume rise situation associated with the battery emissions may have been represented in such a manner that results of the assessment would be overly conservative for the current rulemaking effort. For the assessment presented here, we felt it was pertinent to make an effort to more accurately characterize the complex plume rise situation. Thus, the hybrid modeling effort described above, that combined the BLP plume rise and the ISC dispersion model, was developed to better characterize potential impacts.

Some of the modeling parameters for which there is some flexibility, (i.e., a decision has to be made to include them when preparing the model), are presented in Table D-3. Each parameter has some contribution to the outputs but not to an equal extent. For example, in this assessment, there was a decision to not include model features such as plume depletion by deposition, buoyancy induced dispersion or building downwash effects. The effects of any one of these could affect a concentration prediction or its location in relationship to the facility, but when aggregated with other parts of this assessment (see Table 2-10), we felt that the degree of confidence in the model predictions that is necessary to feed into the rulemaking decision was achieved with the current assessment.

Appendix D References

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Appendix E: Enhanced Plume Rise Calculations

Coke oven facilities produce significant heat from large, parallel oven batteries, which behave as low-level buoyant line sources. Because of the parallel-line source configuration, plume rise is “enhanced” as ambient air is not fully entrained into the plume. The BLP model has been specifically developed to simulate the plume rise from multiple buoyant line sources that are subject to downwash. As such, the plume rise associated with coke oven batteries and pushing fugitive emissions were modeled using the BLP model. Line source dimensions for BLP modeling were developed from the physical size of the battery structure. Representative dimensions and orientation for each battery along with buoyant flux calculations are given below.

Buoyancy flux from convective heat transfer and fugitive emissions was calculated from equations documented in a study performed by Sciences International (1998). The following sections present the background equations and example calculations. The inputs for all coke oven batteries and the results of the buoyancy flux calculations are given in the Tables that follow.

Convective Heat Transfer

Convective heating of the ambient air surrounding hot coke oven surfaces results in the formation of a thermal updraft that entrains coke oven emissions. Convective heat transfer was estimated for doors, oven tops, buckstays, and offtakes. Battery-specific dimensions of these surfaces were provided by each of the coke plants. Convective heat transfer is estimated from Equation E-1 (Sciences International, 1998):

$$Q_h = (H_c \times A_s \times \Delta T)/60 \qquad \text{(E-1)}$$

where

Q_h = Heat transfer rate (Btu/min per source)
H_c = Heat transfer coefficient (Btu/hr/ft^2-°F)
= $0.3\ (\Delta T)^{1/4}$ for vertical surfaces (doors and buckstays)
= $0.38\ (\Delta T)^{1/4}$ for horizontal surfaces (oven top)
= $0.4\ (\Delta T/X)^{1/4}$ for vertical cylinders (offtakes), where *X* is the diameter in inches
A_s = Surface area (ft^2)
= Oven width × oven height (doors)
= Oven width × oven length (oven top)
= 3.14 × diameter × height (offtakes)
= As measured and reported by the companies (buckstays)
ΔT = Temperature of hot surface – ambient temperature (°F)
60 = Conversion factor (min/hr)

The flux per source is calculated from Equation E-2 (Sciences International, 1998):

$$F' = (g \times Q_h \times 1054)/(p \times C_p \times T_a \times 60) \qquad \text{(E-2)}$$

where

F' = Flux per source (m^4/s^3)
g = Constant = 9.81 (m/s^2)
1054 = Energy conversion factor
p = Air density = 1,045 (g/m^3)
C_p = Heat capacity of air = 1.013 (J/g-°K)
T_a = Ambient temperature (°K)
60 = Conversion factor (s/min)

Total flux for the battery for a given type of surface is estimated from Equation E-3:

$$F'_{total} = F' \times \text{number of sources} \qquad \text{(E-3)}$$

where

F'_{total} = Flux per source (m^4/s^3)
number of sources = 2 × number of ovens (doors)
= number of ovens (oven tops)
= number of ovens (offtakes, except for AK Steel–Middletown and AK Steel–Ashland No. 4)
= 2 × number of ovens (offtakes, for AK Steel–Middletown and AK Steel–Ashland No. 4, which have 2 offtakes per oven)
= number of ovens (buckstays)

Example Calculation: Buckstays for AK Steel–Ashland Battery 3

$T_{buckstay}$ = 265 °F
T_a = 55 °F = 286 °K
ΔT = 210 °F
A_s = 125 ft^2 per oven
H_c = $0.3\ (\Delta T)^{1/4} = 0.3\ (210)^{1/4} = 1.14$
Num. of ovens = 76

Substituting into Equation E-1:

$$Q_c = (1.14 \times 125 \times 210)/60 = 499 \text{ Btu/min per oven}$$

Substituting into Equation E-2:

$$F' = (9.81 \times 499 \times 1054)/(1045 \times 1.013 \times 286 \times 60) = 0.284 \text{ m}^4/\text{s}^3 \text{ per oven}$$

Substituting into Equation E-3:

$$F'_{\text{total}} = 0.284 \times 76 = 21.6 \text{ m}^4/\text{s}^3$$

Fugitive Emissions

Buoyancy flux from fugitive emissions was estimated for the following emission sources: charging, door leaks, topside leaks (lids and offtakes), pushing, travel of the quench car, and decarbonizing. The buoyancy flux is estimated by the following sequence of equations (Sciences International, 1998):

Step 1: Estimate emission rate (ER) in lb/hr per oven.

For doors, lids, offtakes, charging, and quench car during travel:

$$ER = EF \times \text{coal rate (tons/hr per oven)} \tag{E-4}$$

where

EF (doors) = 0.02 lb/ton coal
EF (lids and offtakes) = 0.000376 lb/ton coal
EF (charging) = 0.0004 lb/ton coal
EF (quench car) = 0.025 lb/ton coal

The coal rate was provided by each plant.

For decarbonization, ER is given as 3.62 lb/hr per battery.

Step 2: Estimate density (ρ) in lb/ft^3:

$$\rho = 3 \times 10^{-7} \times \text{percent opacity} \tag{E-5}$$

where

percent opacity = 60 (doors, lids, offtakes, charging, and decarbonizing)
= 10 (quench car during travel)

Step 3: Estimate volumetric flow rate (V_f) in m^3/s per oven (for decarbonizing, V_f is the total for the battery):

$$V_f = ER\ (\text{lb/hr}) / p\ (\text{lb/ft}^3) \times 7.87 \times 10^{-6}\ (\text{m}^3\text{/s per ft}^3\text{/hr}) \qquad \text{(E-6)}$$

For pushing, the volumetric flow rate is given in Table E-1.

Step 4: Estimate buoyancy flux (F ') in m^4/s^3 for doors, lids/offtakes, charging, quench car.

$$F' = g \times V_f \times (1-T_a/T_e) \times \text{number of ovens} \qquad \text{(E-7)}$$

where

g = $9.81\ m/s^2$
T_a = Ambient temperature (°K)
T_e = Exit temperature of fugitive emissions (°K)
T_e = 626 °K (charging)
T_e = 1,033 °K (pushing and quench car)
T_e = 1,088 °K (doors, lids, offtakes)

Table E-1. Volumetric Flow Rate Estimates for Pushing Emissions

Facility	Flow (ft^3/hr per oven)	Flow (m^3/s per oven)
AK Middletown	122	9.60×10^{-4}
AK Ashland No. 3	122	9.60×10^{-4}
AK Ashland No. 4	204	1.61×10^{-3}
Tonawanda (uncontrolled)	2100	1.65×10^{-2}
Erie Coke A and B	79	6.22×10^{-4}
Erie Coke (scrubber car)	38	2.99×10^{-4}

For decarbonization, the flux is estimated from Equation E-8:

$$F' = g \times V_f \times (1-T_a/T_e) \qquad \text{(E-8)}$$

where

T_e decarbonization = 1,255°K

Example Calculation: Charging for AK Steel–Ashland Battery 3:

EF = 0.0004 lb/ton coal
coal rate = 0.8 ton/hr per oven

percent opacity = 60
T_a = 286 °K
T_e = 626 °K
num. of ovens = 76

Substituting into Equation E-4:

$$ER = 0.0004 \times 0.8 = 0.00032 \text{ lb/hr per oven}$$

Substituting into Equation E-5:

$$\rho = 3 \times 10^{-7} \times 60 = 1.8 \times 10^{-5} \text{ lb/ft}^3$$

Substituting into Equation E-6:

$$V_f = (0.00032/1.8 \times 10^{-5}) \times 7.87 \times 10^{-6} = 1.4 \times 10^{-4} \text{ m}^3\text{/s per oven}$$

Substituting into Equation E-7:

$$F' = 9.81 \times 1.4 \times 10^{-4} \times (1 - 286/626) \times 76 = 0.057 \text{ m}^4\text{/s}^3$$

Estimates of the Volumetric Flow Rate of Fugitive Pushing Emissions

The approach for calculating estimates of the volumetric flow rate of fugitive pushing emissions is similar to the approach used to calculate fugitive emissions. It is based on dividing an estimate of the emission rate in lb/hr by an estimate of the concentration in lb/ft^3 to get a volumetric flow rate in ft^3/hr. The difference is that the estimates of emission rate and concentration are derived from two U.S. Environmental Protection Agency (EPA) tests rather than based on assumptions.

In 1998, EPA conducted tests of pushing emissions at two batteries—a foundry coke battery at ABC Coke (U.S. EPA, 1999b) and a furnace coke battery at Bethlehem Steel (Burns Harbor) (U.S. EPA, 1999a). Emissions of particulate matter (PM) were sampled in the capture system before the control device and in the stack after the control device. The results for the emissions captured before the control device were used to develop estimates of the concentration of pushing emissions, the rate of uncontrolled emissions, and the rate of fugitive emissions escaping capture.

Estimate of Emission Rates

The emission rate for captured PM emissions at ABC Coke was 1.46 lb/ton of coke compared with 1.90 lb/ton of coke at Bethlehem Steel. A 1998 EPA survey of the industry (U.S. EPA, 1999a) found that capture systems for pushing emissions were designed to capture 90 to 99 percent of the pushing emissions. Using a midrange or typical capture efficiency of 95 percent, uncontrolled emissions can be estimated from

ABC Coke = 1.46 lb/ton ÷ 0.95 = 1.5 lb/ton foundry coke
Bethlehem = 1.90 lb/ton ÷ 0.95 = 2.0 lb/ton furnace coke

A capture efficiency of 95 percent means that 5 percent of the emissions escape capture. Consequently, fugitive emissions escaping capture are estimated as

ABC Coke = 1.5 lb/ton × 0.05 = 0.075 lb/ton foundry coke
Bethlehem = 2.0 lb/ton × 0.05 = 0.10 lb/ton furnace coke

Estimate of Concentration

Table E-2 illustrates the calculation of the concentration (in lb/ft^3) using the test results. The analysis assumes that uncontrolled PM emissions and fugitive emissions escaping capture have the same concentration as that measured in the capture hood. Facility-specific results are summarized in Table E-3.

Table E-2. Estimate of PM Concentration

Parameter	ABC Coke	Bethlehem Steel
lb PM/ton of coke	1.46	1.9
ft^3/min[a]	61000	77200
tons coke/push	12	20
push time (min)	1	1
lb PM/push	1.46 × 12 = 17.5	1.90 × 20 = 38
ft^3/push[a]	61000	77200
lb PM/ft^3	$17.5/61,000 = 2.9 \times 10^{-4}$	$38/77,200 = 4.9 \times 10^{-4}$

[a] A push lasts for 1 minute, so the ft^3 evacuated during the push (i.e., the volume that contains the PM that was captured) is the evacuation rate in ft^3/min × 1 minute.

Estimate for AK Steel–Middletown

AK Steel has a capture and control system for pushing emissions, and the control device discharges from a stack remote from the battery. Consequently, the emissions of interest are fugitive pushing emissions that escape capture. The plant reported an annual furnace coke production rate of 423,000 tons per year from 76 ovens, which yields 0.6 tons of coke/hr per oven. Using the emission factor from

Section E3.3 above (0.10 lb PM/ton of coke for furnace coke), fugitive emissions would be

0.6 tons/hr × 0.10 lb/ton = 0.06 lb/hr per oven.

Using the concentration (4.9×10^{-4} lb/ft^3) gives a flow rate of

0.06 lb/hr ÷ 4.9×10^{-4} lb/ft^3 = 122 ft^3/hr per oven = 3.4 m^3/hr per oven

Estimate for AK Steel–Ashland

This plant also has a capture and control system.

- Battery 3 (376,000 ton/yr from 76 ovens = 0.6 tons/hr per oven):

0.6 tons/hr × 0.10 lb/ton = 0.06 lb/hr per oven.

Using the concentration (4.9×10^{-4} lb/ft^3) gives a flow rate of

0.06 lb/hr ÷ 4.9×10^{-4} lb/ft^3 = 122 ft^3/hr per oven = 3.4 m^3/hr oven

- Battery 4 (589,000 tons/yr from 70 ovens = 1.0 tons/hr):

1.0 tons/hr × 0.10 lb/ton = 0.1 lb/hr per oven.

0.1 lb/hr ÷ 4.9×10^{-4} lb/ft^3 = 204 ft^3/hr per oven = 5.8 m^3/hr oven

Estimate for Tonawanda Coke

The calculation for Tonawanda Coke is similar except that pushing emissions are uncontrolled and the plant produces foundry coke (219,000 tons/yr from 60 ovens = 0.4 tons/hr per oven). Using the uncontrolled emission factor (1.5 lb PM/ton of coke for foundry coke), fugitive emissions would be

0.4 tons/hr × 1.5 lb/ton = 0.6 lb/hr per oven.

Using the concentration (2.9×10^{-4} lb/ft^3) gives a flow rate of

0.6 lb/hr ÷ 2.9×10^{-4} lb/ft^3 = 2,100 ft^3/hr per oven = 59.5 m^3/hr oven

Estimate for Erie Coke

Erie Coke has a mobile scrubber car to control pushing emissions, and it has a short stack that discharges at the side of the battery. Consequently, flow is contributed by both fugitive emissions that escape capture and the discharge from the short stack at the side of the battery. The two small batteries produce foundry coke.

- Battery A (65,100 ton/yr from 23 ovens = 0.3 tons/hr per oven):

$$0.3 \text{ tons/hr} \times 0.075 \text{ lb/ton} = 0.023 \text{ lb/hr per oven.}$$

Using the concentration (2.9×10^{-4} lb/ft^3) gives a flow rate of

$$0.023 \text{ lb/hr} \div 2.9 \times 10^{-4} \text{ lb/ft}^3 = 79 \text{ ft}^3\text{/hr per oven} = 2.2 \text{ m}^3\text{/hr oven}$$

- Battery B (99,000 ton/yr from 35 ovens = 0.3 tons/hr per oven):

$$0.3 \text{ tons/hr} \times 0.075 \text{ lb/ton} = 0.023 \text{ lb/hr per oven.}$$

$$0.023 \text{ lb/hr} \div 2.9 \times 10^{-4} \text{ lb/ft}^3 = 79 \text{ ft}^3\text{/hr per oven} = 2.2 \text{ m}^3\text{/hr oven}$$

- Scrubber car stack: data are available from an emission test performed in 1998 (Advanced Technology Systems, 1998). The scrubber car discharges for 2 minutes per push, and there are 1.8 pushes per hour. During the two minutes, the average flow rate was 37,300 ft^3/min. Over a 1-hour period, the volume discharged would be :

$$37{,}300 \text{ ft}^3\text{/min} * 2 \text{ min/push} * 1.8 \text{ pushes/hour} = 134{,}000 \text{ ft}^3\text{/hour} = 2{,}200 \text{ ft}^3\text{/min}$$

There are a total of 58 ovens, so: 2,200/58 = 38 ft^3/min/oven (1.1 m^3/hr)

Table E-3. Summary of Estimates

Plant	Flow (ft^3/hr per oven)	Comment
AK Middletown	122	for fugitives escaping capture
AK Ashland No. 3	122	for fugitives escaping capture
AK Ashland No. 4	204	for fugitives escaping capture
Tonawanda	2100	for uncontrolled emissions
Erie Coke A and B	79	for fugitives escaping capture
Erie Coke scrubber	38	scrubber stack at 84°F

Summary of Results and Inputs

The buoyancy flux estimates are summarized in Table E-4. Table E-5 presents the inputs used to estimate convective heat rates, and Table E-6 gives the inputs used to calculate the contribution from fugitive emissions.

Table E-4. Summary of Buoyancy Flux Estimates (m^4/s^3)

Convective	AK Steel-Middle. No.3	AK Steel-KY No.3	AK Steel-KY No.4	Erie Coke A	Erie Coke B	Tonawanda No.2
Doors	10.04	8.50	7.83	5.60	7.54	9.69
Oven tops	11.75	17.23	18.15	7.83	11.51	19.78
Buckstays	15.13	21.64	19.93	3.22	5.06	14.78
Lids and offtakes	7.34	3.10	13.47	2.80	3.73	7.65
Fugitives						
Pushing	0.52	0.52	0.80	0.10	0.16	7.07
Charging[a]	0.06	0.06	0.09	0.01	0.01	0.03
Door leaks[a]	4.33	3.84	6.19	3.50	5.33	11.43
Lid and offtake leaks[a]	0.08	0.07	0.12	0.07	0.10	0.21
Quench car travel	31.87	28.26	45.54	4.30	6.54	14.02
Decarbonization	12.00	11.97	11.97	12.02	12.02	12.02
TOTAL F′	**93.1**	**95.2**	**124.1**	**39.5**	**52**	**96.7**

[a] This risk assessment provides emissions and risk numbers for MACT I allowable emission rates as well as emissions rates estimated from actual reported data and emission rates expected at the LAER level of emissions. Changes in the emission rates for charging, door leaks, and lid/offtake leaks would not be expected to affect buoyancy flux calculations because their contribution to the total convective heat output would be negligible. For example, the total MACT I mass rate of emissions contributes only 7.7% (average of 4 to 12% across the 6 batteries) to the total buoyancy flux across all plants.

Table E-5. Inputs for Convective Heat Calculations

	AK Steel-Middletown No.3	AK Steel-Ashland No.3	AK Steel-Ashland No.4	Erie Coke A	Erie Coke B	Tonawanda No.2
Number of ovens[a]	76	76	70	23	35	60
Offtakes per oven[a]	2	1	2	1	1	1
Oven height, ft[a]	13.1	13.1	13.1	11.5	11.5	13.1
Oven width, ft[a]	1.5	1.5	1.5	3.8	3.7	2.7
Oven length, ft[a]	41	43.2	49.4	43	43	43.8
Offtake diameter, ft[a]	1.16	1.17	1.67	1.917	1.75	1.7
Offtake height, ft[a]	5.5	5.83	10.54	6	6	6.5
Buckstay area, ft^2 per oven	130	125	125	116	121	142
Door temperature, °K	443[a]	425[a]	425[a]	417[a]	407[a]	397[a]
Oven top temperature, °K	388[a]	422[a]	422[a]	370[a]	370[a]	394[a]
Buckstay temperature, °K	368[a]	402[a]	402[a]	351[a]	350[a]	375[a]
Offtake temperature, °K	447[a]	422[a]	422[a]	516[a]	504[a]	527[a]
Door temperature, °F	337	306[a]	306[a]	291[a]	273[a]	256[a]
Oven top temperature, °F	239[a]	300[a]	300[a]	207[a]	206[a]	250[a]
Buckstay temperature, °F	204[a]	265[a]	265[a]	172[a]	171[a]	215[a]
Offtake temperature, °F	346[a]	300[a]	300[a]	469[a]	448[a]	490[a]
Ambient temperature, °F[b]	52	55	55	47	47	48
Ambient temperature, °K[b]	284	286	286	282	282	282

[a] Site-specific data provided by the company.

[b] Site-specific mean annual temperature.

[c] Default value from Sciences International (1998) (for Geneva Steel).

Table E-6. Inputs for Fugitive Emission Calculations

	AK Steel-Middletown No.3	AK Steel-Ashland No.3	AK Steel-Ashland No.4	Erie Coke A	Erie Coke B	Tonawanda No.2
Number of ovens[a]	76	76	70	23	35	60
Coal (ton/hr/oven)[a]	0.9	0.8	1.4	0.4	0.4	0.5
Coke (ton/hr/oven)[a]	0.64	0.57	0.96	0.32	0.32	0.42
Ambient temperature, °K [b]	284	286	286	282	282	282
Pushing flow rate, ft^3/hr per oven[c]	122	122	204	79	79	2100
Pushing temperature, °K[d]	1033	1033	1033	1033	1033	1033
Charging temperature, °K[d]	626	626	626	626	626	626
Percent opacity, charging[d]	60	60	60	60	60	60
PM_{10} lb/ton coal, charging[e]	0.0004	0	0.0004	0.0004	0.0004	0.0004
Door temperature, °K[d]	1088	1088	1088	1088	1088	1088
Percent opacity, doors[d]	60	60	60	10	10	10
PM_{10} lb/ton coal, doors[e]	0.02	0.02	0.02	0.02	0.02	0.02
Lid/offtake temperature, °K[d]	1088	1088	1088	1088	1088	1088
Percent opacity, lids/offtakes[d]	60	60	60	10	10	10
PM_{10} lb/ton coal, lids/offtakes[e+]	0.000376	0	0.000376	0.000376	0.000376	0.000376
Travel temperature, °K[d]	1033	1033	1033	1033	1033	1033
Percent opacity, travel[d]	10	10	10	10	10	10
PM10 lb/ton coal, travel[f]	0.025	0.025	0.025	0.025	0.025	0.025
Decarbonization temperature, °K[d]	1255	1255	1255	1255	1255	1255
Percent opacity, decarbonization[e]	60	60	60	60	60	60
PM10 lb/hr per battery, decarbonization[d]	3.62	3.62	3.62	3.62	3.62	3.62

[a] Site-specific data provided by the company.

[b] Site-specific mean annual temperature.

[c] As derived in Section E3.

[d] Value from Sciences International (1998) except Tonawanda Coke and Erie Coke provided estimates of 10 percent opacity for doors, lids, and offtakes.

[e] From AP-42 draft revision dated 1999. This document has been replaced by the draft document dated 2001 (US EPA , 2001)

[f] Emissions during travel assumed to be 25 percent of fugitive pushing emissions (0.1 lb/ton).

Model Parameter Sensitivity Analysis: Representative Stack Configuration

To determine the appropriate number of "representative " stacks to simulate a coke oven battery, a sensitivity analysis examining different configurations was performed. The sensitivity analysis consisted of a comparison of the air modeling results using both 14 stacks and 36 stacks. If the dispersion modeling results were unchanged (within an acceptable margin) when the stack number was increased from 14 to 36, it could be concluded that 14 stacks was sufficient to simulate the dispersion of emissions from coke batteries. If the results were considered different, the number of stacks would be increased until convergence is reached. For this analysis, a difference of 10 percent was used.

The AK Steel—Ashland facility's batteries 3 and 4 and the Erie Coke's batteries A and B were used in this analysis. These two facilities were selected because both facilities have two batteries, so the comparison can be made for each pair of batteries. AK Steel—Ashland represents a large coke oven battery and Erie Coke represents a small coke oven battery.

Five years of meteorological data were used in this analysis. The annual average unitized air concentrations, dry deposition rates, and wet deposition rates were used in the comparisons. The polar receptor grid from the facility centroid up to 50 km was used.

For AK Steel - Ashland, eight dispersion modeling runs were made for each battery, as follows:

- Battery 3 with 36 stacks for vapors
- Battery 3 with 36 stacks for particulates
- Battery 3 with 14 stacks for vapors
- Battery 3 with 14 stacks for particulates
- Battery 4 with 36 stacks for vapors
- Battery 4 with 36 stacks for particulates
- Battery 4 with 14 stacks for vapors
- Battery 4 with 14 stacks for particulates.

The ratios between 14 stacks and 36 stacks were calculated for air concentrations, dry deposition, and wet deposition. The comparison shows that the results are very similar between 14 and 36 virtual stacks. For example, the maximum difference in particle concentrations for battery 3 is only about 2%. For battery 3, the differences in dry deposition rates are less than 2% at 99.9% of receptor locations. The maximum difference of dry deposition rate is about 5%. The differences in wet deposition rate for battery 3 are less than 2% at all receptor locations.

The comparison of results for battery 4 are similar to those for battery 3. However, the differences are generally slightly greater than those for battery 3. There are a few cases where the differences are greater than 10%, but this is caused by the limited number of decimal places that the ISCST3 output reports. The large percentage differences between the 14 and 36 stack configurations are at locations where the actual value is close to zero. If the results were reported in scientific notation instead of a fixed number of decimal places, then the percentage difference would not be expected to be nearly as large. The differences for vapor runs between 14 and 36 stacks are similar to those of particle runs.

The comparison for Erie Coke runs shows that the differences in air concentration and deposition rates between 14 and 36 virtual stacks are less than those for AK Steel—Ashland. This is because Erie Coke's batteries are smaller than the batteries at AK Steel—Ashland, and the spaces between stacks are therefore smaller.

Table E-7 shows the mean and the standard deviation of the ratios. Based on the results from this analysis, it was decided that a coke oven battery can be properly modeled using 14 stacks.

Table E-7. Mean and Standard Deviation: Ratios of the "36-Stack" and the "14-Stack Results"

Facility	Battery	Particle or Vapor	Ratio					
			Air Concentration		Dry Deposition		Wet Deposition	
			Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
AK Steel-Ashland	3	Particle	1.0001	0.0011	1.0001	0.0019	1.0001	0.0015
AK Steel-Ashland	3	Vapor	1.0001	0.0011	N/A	N/A	1.0001	0.0018
AK Steel-Ashland	4	Particle	1.0012	0.0195	1.0006	0.0140	1.0003	0.0029
AK Steel-Ashland	4	Vapor	1.0008	0.0167	N/A	N/A	1.0003	0.0025
Erie Coke	A	Particle	1.0002	0.0015	1.0002	0.0017	1.0001	0.0027
Erie Coke	A	Vapor	1.0002	0.0015	N/A	N/A	1.0002	0.0016
Erie Coke	B	Particle	1.0007	0.0080	1.0007	0.0078	0.9998	0.0100
Erie Coke	B	Vapor	1.0007	0.0080	N/A	N/A	0.9998	0.0100

N/A = Not Applicable

Buoyancy Inducted Dispersion Sensitivity Calculation

Downwind Distance: 1 km
Stability: D
Plume Rise: 50m
PG Sigma Y: 70 m
PG Sigma Z: 35 m

Buoyancy induced dispersion (effective dispersion terms) are calculated from the following formulas (USEPA, 1995):
Effective vertical dispersion σ_{ze} is calculated as follows:

$$\sigma_{ye} = \left[\sigma_y^2 + \left(\frac{\Delta h}{3.5}\right)^2\right]^{1/2} \tag{E-2}$$

Effective horiziontal dispersion σ_{ye} is calculated as follows:

$$\sigma_{ze} = \left[\sigma_z^2 + \left(\frac{\Delta h}{3.5}\right)^2\right]^{1/2} \tag{E-1}$$

Effective Sigma Y: 71 m
Effective Sigma Z: 38 m

Appendix E References

Advanced Technology Systems. 1998. Measurement of Particulate Matter Emissions from a Coke Quench Car Scrubber Exhaust Duct. Prepared for Erie Coke Corporation. October.

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U.S. EPA (Environmental Protection Agency). 1995: User's Guide for the Industrial Source Complex (Isc3) Dispersion Models Volume II - Description of Model Algorithms; EPA-454/B-95-003b; RTP, NC

U.S. EPA (Environmental Protection Agency). 1999b. Emissions Testing of Combustion Stack and Pushing Operations at Coke Battery No. 5/6 at ABC Coke in Birmingham, Alabama. EPA-454/R-99-002a.

U.S. EPA (Environmental Protection Agency). 1999a. Emissions Testing of Combustion Stack and Pushing Operations at Coke Battery No. 2 at Bethlehem Steel Corporation's Burns Harbor Division in Chesterton, Indiana. EPA-454/R-99-001a.

U.S. EPA (Environmental Protection Agency). 2001. Emission Factor Documentation for AP-42 Section 12.2: Coke Production. Revised Draft Version as of July 2001.

Appendix F: Source Parameters Used in Dispersion Modeling

Model inputs for each facility are repeated in the following Tables as:

Source input parameters:

Point
Stack Height = Vertical Dimension
Stack Diameter = Lateral Dimension

Volume emission rate = 1 g/s (grams/second)
Release Height = Vertical Dimension /2
Sigma Y (lateral dimension of volume) = Lateral Dimension /4.3
Sigma Z (vertical dimension of volume) = Vertical Dimension / 2.15

Area emission rate = g/s per m^2 (diameter of stack value)
Release Height = Vertical Dimension
Initial X and Y dimensions = Lateral Dimension (diameter of circle)
Initial Sigma Z = Vertical Dimension / 2.15

Emission rates for each facility:
Emission rates grams/second for volume and point sources
grams/second per m^2 for area sources

Area source (volume sources) for all BPP emission sources total 1 with each emission point contribution equal to their emissions contribution. For example, for AK-Middletown, BPP1 to BPP9 emission rates total 1 with emission contribution from Table C-54 providing the proportions. The remaining facility information is as follows:

AK- Ashland - BPP1 to BPP15 emission rates total 1; See Table C-55
Erie - BPP1 to BPP4 emission rates total 1: See Table C-56
Tonawanda - BPP1 to BPP7 emission rates total 1

Table F-1. Source Parameters - AK Steel Middletown

Source ID	Source Name	Source Type	Particulate /Vapor	Emission Rate (g/s)	Vertical Dimension (m)	Lateral Dimension (m)	Exit Temp. (K)	Exit Velocity (m/s)
BAT	Coke Battery	Point	PV	1	7.0	5.2	**	0.0001
BPP1	Tar decanter	Volume	V	0.2485	3.0	14.1		
BPP2	Tar intercepting sump	Area circ	V	0.043	3.4	14.3		
BPP3	Tar dewatering tank	Volume	V	0.095	3.0	6.7		
BPP4	Tar storage tank	Volume	V	0.0859	12.2	17.2		
BPP5	Flushing liquor circulation tank	Volume	V	0.0587	3.0	10.7		
BPP6	Excess ammonia liquor tank	Volume	V	0.0064	3.0	23.4		
BPP7	Wash oil decanter	Volume	V	0.0168	3.0	9.8		
BPP8	Tank truck loading- tar	Area circ	V	0.2509	2.0	14.1		
BPP9	Fugitive emissions-wastewater	Area circ	V	0.1948	1.0	46.9		
COM	Combustion stack***	Point	PV	1	76.2	4.3	518	5.2
PCD1	Pushing control device	Point	PV	1	4.6	0.9	305	32.6
PCD2	Pushing control device	Point	PV	1	4.6	0.9	305	32.6
PCD3	Pushing control device	Point	PV	1	10.4	.9	305	32.6
QCT	Quench tower	Point	PV	1	30.5	4.3	378	6.3

** Coke battery temperatures are not an input to the ISCST dispersion model. These temperatures are input into the BLP model and used in the calculation of convective heat rates (Table E-5) and plume rise.

*** A combustion stack handles the emissions from the fuel source which heats the coke ovens. These are located away from the batteries, and their emissions were not modeled as part of the emissions used to calculate plume rise. They were modeled directly with ISCST3.

Table F-2. Source Parameters - AK Steel Ashland

Source ID	Source Name	Source Type	Particule /Vapor	Emission Rate (g/s)	Vertical Dimension (m)	Lateral Dimension (m)	Exit Temp. (K)	Exit Velocity (m/s)
BAT3	Coke Battery #3	Point	PV	1	7.0	9.7	**	0.0001
BAT4	Coke Battery #4	Point	PV	1	7.0	9.7	**	0.0001
BPP1	Light oil storage tank	Volume	V	0.0121	5.8	18.3		
BPP2	Tar decanter	Volume	V	0.1105	8.2	24.4		
BPP3	Tar intercepting sump	Area circ	V	0.0191	2.4	2.4		
BPP4	Tar dewatering tank	Volume	V	0.0422	5.5	18.3		
BPP5	Tar storage tank	Volume	V	0.0382	10.1	85.3		
BPP6	Light oil condenser vent	volume	V	0.1809	4.0	3.0		
BPP7	Light oil sump	Area circ	V	0.0301	2.4	2.4		
BPP8	Flushing liquor circulation	Volume	V	0.0261	10.4	18.3		
BPP9	Excess ammonia liquor tank	Volume	V	0.0028	10.4	36.6		
BPP10	Wash oil decanter	Volume	V	0.0076	4.0	3.0		
BPP11	Wash oil circulation tank	Volume	V	0.0076	4.0	3.0		
BPP12	Tank truck loading- light oil	Area circ	V	0.2916	2.0	10.0		
BPP13	Tank truck loading- tar	Area circ	V	0.0281	2.0	10.0		
BPP14	Fugitive emissions-	Area circ	V	0.0469	1.0	24.4		
BPP15	Fugitive equip. leaks-light oil	Area circ	V	0.1562	0.0	67.1		
COM3	Combustion stack- #3 ***	Point	PV	1	56.1	2.9	505	3.9
COM4	Combustion stack- #4 ***	Point	PV	1	67.1	3.8	554	7.9
PCD	Pushing control device	Point	PV	1	18.0	0.9	311	18.8
QCT3	Quench tower #3	Point	PV	1	21.0	9.5	378	2.1
QCT4	Quench tower #4	Point	PV	1	21.0	11.4	378	1.4

** Coke battery temperatures are not an input to the ISCST dispersion model. These temperatures are input into the BLP model and used in the calculation of convective heat rates (Table E-5) and plume rise.

*** A combustion stack handles the emissions from the fuel source which heats the coke ovens. These are located away from the batteries, and their emissions were not modeled as part of the emissions used to calculate plume rise. They were modeled directly with ISCST3.

Table F-3. Source Parameters - Erie Coke

Source ID	Source Name	Source Type	Particulate /Vapor	Emission Rate (g/s)	Vertical Dimension (m)	Lateral Dimension (m)	Exit Temp. (K)	Exit Velocity (m/s)
BAT-A	Coke Battery- A	Point	PV	1	7.0	8.0	**	0.0001
BAT-B	Coke Battery- B	Point	PV	1	7.0	8.8	**	0.0001
BPP1	Excess ammonia liquor tank	Volume	V	0.4331	10.7	14.6		
BPP2	Excess ammonia liquor tank	Volume	V	0.1444	2.4	9.1		
BPP3	Tank truck loading - tar	Area	V	0.2113	2.0	10.0		
BPP4	Fugitive emissions -	Area	V	0.2113	7.6	34.1		
COM	Combustion stack ***	Point	PV	1	57.9	2.4	513	3.8
QCT	Quench tower	Point	PV	1	15.2	9.6	378	1.0

** Coke battery temperatures are not an input to the ISCST dispersion model. These temperatures are input into the BLP model and used in the calculation of convective heat rates (Table E-5) and plume rise.

*** A combustion stack handles the emissions from the fuel source which heats the coke ovens. These are located away from the batteries, and their emissions were not modeled as part of the emissions used to calculate plume rise. They were modeled directly with ISCST3.

Table F-4. Source Parameters - Tonawanda

Source ID	Source Name	Source Type	Particul. /Vapor	Emission Rate (g/s)	Vertical Dimension (m)	Lateral Dimension (m)	Exit Temp. (K)	Exit Velocity (m/s)
BAT2	Coke battery #2	Point	PV	1	7.0	10.1	**	0.0001
BPP1	Light oil storage tank	Volume	V	0.1083	3.7	21.3		
BPP2	Excess ammonia liquor tank	Volume	V	0.0349	9.1	21.3		
BPP3	Ammonia still building	Volume	V	0.2228	24.4	30.5		
BPP4	Tank truck loading- light oil	Area circ	V	0.0668	0.6	12.2		
BPP5	Tank truck loading - tar	Area circ	V	0.0095	0.6	12.2		
BPP6	Fugitive emissions - wastewater	Area circ	V	0.0406	0.3	15.2		
BPP7	Fugitive equip. leaks - light oil	Area circ	V	0.5171	18.3	16.8		
COM	Combustion stack ***	Point	PV	1	54.9	2.7	478	7.8
QCT	Quench tower	Point	PV	1	12.2	9.2	378	1.2

** Coke battery temperatures are not an input to the ISCST dispersion model. These temperatures are input into the BLP model and used in the calculation of convective heat rates (Table E-5) and plume rise.

*** A combustion stack handles the emissions from the fuel source which heats the coke ovens. These are located away from the batteries, and their emissions were not modeled as part of the emissions used to calculate plume rise. They were modeled directly with ISCST3.

Table F-5. BLP Model Inputs

	Ashland 3	**Ashland 4**	**Erie A**	**Erie B**	**Middletown**	**Tonawanda**
Plume Rise Parameters						
Average Building Length (m)	57.61	57.61	41.57	41.57	57.60	66.80
Average Building Height (m)	07.01	07.01	07.01	07.01	07.01	07.01
Average Building Width (m)	13.71	13.71	13.10	13.10	12.50	13.36
Average Line Source Width (m)	00.61	00.61	00.61	00.61	00.61	00.61
Avg Spacing Between Buildings	10.00	10.00	12.19	12.19	10.00	10.00
Avg Line Source Buoyancy Parameter (F') (m^4s^3)	109.65	109.65	45.75	45.75	93.10	96.70
Line Source Attributes						
X-coordinate of beginning of line source (m)	0.00	133.81	0.00	62.13	0.00	0.00
Y-coordinate of beginning of line source (m)	0.00	0.01	0.00	0.01	0.00	0.00
X-coordinate of end of line source (m)	57.61	186.85	49.94	95.33	57.60	66.80
Y-coordinate of end of line source (m)	0.00	0.01	0.00	0.01	0.00	0.00
Release height of line source (m)	7.01	7.01	7.01	7.01	7.01	7.01
Pollutant emission rate of line source (g/s)	1.0	1.0	1.0	1.0	1.0	1.0
Line Source base elev. (m)	0	0	0	0	0	0

Appendix G: Calculation of Fraction of Pollutant Air Concentration in the Vapor Phase (*F_v*)

F_v was determined based on data and calculations in the *Human Health Risk Assessment Protocol* (U.S. EPA, 1998). For metals (except mercury), F_v was set to 0 because metals are not present in the vapor phase. For benzene soluble organics (BSO), F_v was set to 1. For all other organics in this analysis, F_v was calculated using the following equation:

$$F_v = 1 - \frac{c \times S_T}{VP_1 + (c \times S_T)} \qquad \text{(G-1)}$$

where:

c = Junge constant with a value of $1.7\text{x}10^{-4}$ (atm-cm)
S_T = Average surface area of particulates, set to $3.5\text{x}10^{-6}$
VP_l = Liquid-phase vapor pressure (atm).

VP_l was derived from the melting point and vapor pressure of the chemical. For vapor pressure greater than $1\text{x}10^{-4}$, F_v was set to 1 because the chemical would be mostly in the vapor phase. If the vapor pressure was less than $1\text{x}10^{-4}$ and the melting point was less than 298K, VP_l was set to the vapor pressure. If the vapor pressure was less than $1\text{x}10^{-4}$ and the melting point was greater than or equal to 298K, then the vapor pressure at ambient temperature is the solid vapor pressure (VP_s) and VP_l was derived using the following equation:

$$VP_1 = [\exp[\frac{\frac{\Delta S_f}{R} \times (MP - 298)}{298}]] \times VP_s \qquad \text{(G-2)}$$

where

ΔS_f = Entropy of fusion [$\Delta S_f/R = 6.79$ (unitless)]
R = Universal gas constant (atm-m^3/mole$^-$K)
MP = Melting point
VP_s = Solid-phase vapor pressure

Appendix G Reference

U.S. EPA (Environmental Protection Agency). 1998. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Volume One.* EPA-530-D-98-001A. Office of Solid Waste and Emergency Response, Washington, DC.

Appendix H: Exposure Duration Distribution

Human exposure data for the probabilistic analysis were obtained from the U.S. Environmental Protection Agency's (EPA's) *Exposure Factors Handbook* (EFH) (U.S. EPA, 1997). Exposure duration was assumed to be equivalent to the average residence time. Exposure duration for the general population was determined using data on residential occupancy from the EFH, Table 15-167 (U.S. EPA, 1997). The data represent the total time a person is expected to live at a single location. The table presented male and female data combined, which were used for the analysis, as well as male-only and female-only data. These data are provided in Table H-1 below. The exposure duration distribution was capped at 70 years (indicated as p100), based on EPA policy. In the probabilistic analysis, exposure duration values were randomly selected from the cumulative distribution.

Inhalation cancer risk is a function of exposure duration. Exposure duration is the only exposure parameter included in the inhalation risk calculation given the unit risk estimate (URE)- based approach used in this analysis. Inhalation rate is not considered because of uncertainty associated with relating UREs to specific inhalation rates.

Table H-1. Exposure Duration Distribution Data

Statistic	Residential Occupancy Period (yr)
p05	2
p10	2
p25	3
p50	9
p75	16
p90	26
p95	33
p98	41
p99	47
p99.5	51
p99.8	55
p99.9	59
p100	70

Appendix H Reference

U.S. EPA (Environmental Protection Agency). 1997. *Exposure Factors Handbook, Volume III, Activity Factors.* EPA/600/P-95/002Fa. Office of Research and Development, Washington, DC. August.

Appendix I: Cancer Risk Cumulative Probability Distributions

The tables presented in this Appendix show the cumulative probability for a series of risk ranges. Cumulative probability is calculated by adding probabilities for sequential risk ranges, or bins. The probability for each risk bin assumes a 70-year exposure duration.

The population counts give the number of people across the entire 50 kilometer site experiencing each risk level. The population count for "All Sources" reflects risk due to emissions from all emission sources combined; the counts for individual emission sources reflect the risk due to each source considered individually. The count for "All Sources" is not a summation of the counts for the individual sources, because a given risk level (e.g., $1x\ 10^{-5}$) will occur at different places and affect different numbers of people for each individual source or combination of sources. These data are the source of the maximum risk values in Table 3-9.

The tables indicate that the primary contributors to risks above 1 in a million ($1x10^{-6}$) are generally pushing fugitives and battery-related emission sources (charging, doors, lids, and offtakes). As noted in Table 3-13 of this report, door leaks are the major component of the battery-related emissions. Quenching is also a large contributor to risk at both AK Steel - sites, but is less of a contributor at the Erie Coke and Tonawanda sites. This difference is consistent with differences in quenching emissions at the four sites (see Table C-11). By-product plant emissions are relatively low contributor to risk (fewer people in risk bins above 1 in a million), particularly for Erie Coke. As shown in Table C-17, Erie Coke has significantly lower by-product plant emissions than the other three sites.

Table I-1. Cancer Risk Cumulative Probability Distribution for AK Steel Middletown:
By Emission Source for 50 kilometer Site

Risk Bin	Cumulative Probability[1]	Population Count				
		All Sources	MACT I Battery Emissions (charging, doors, lids, offtakes)	By-product Plant	MACT II	
					Pushing Fugitives	Quenching
$6x10^{-5}$	0	0	0	0	0	0
$5x10^{-5}$	0.0009	22	0	0	0	0
$4x10^{-5}$	0.03	620	0	0	0	0
$3x10^{-5}$	0.2	3,220	0	2	0	0
$2x10^{-5}$	0.6	10,839	940	77	932	0
$1x10^{-5}$	2.4	41,998	15,071	90	13,601	0
$9x10^{-6}$	2.6	3,439	3,484	26	3,179	0
$8x10^{-6}$	2.7	1,692	1,786	28	1,488	0
$7x10^{-6}$	2.7	1,411	1,605	28	1,444	0
$6x10^{-6}$	2.8	1,739	2,085	40	2,097	0
$5x10^{-6}$	3.3	12,613	5,150	66	5,170	0
$4x10^{-6}$	3.9	13,635	9,904	111	8,667	3,702
$3x10^{-6}$	5.3	32,686	16,725	149	18,440	10,136
$2x10^{-6}$	10.5	120,065	18,407	299	13,904	21,891
$1x10^{-6}$	21.3	251,591	42,481	629	39,953	33,608
$9x10^{-7}$	25.8	103,905	14,424	271	16,553	19,507
$8x10^{-7}$	32.5	156,602	21,899	524	18,601	20,227
$7x10^{-7}$	42.5	233,503	18,688	719	22,540	24,637
$6x10^{-7}$	52.3	227,089	26,762	1,080	19,946	32,819
$5x10^{-7}$	67.2	348,396	108,650	2,341	100,059	107,985
$4x10^{-7}$	86.8	455,992	115,811	4,934	102,748	132,888
$3x10^{-7}$	99.8	302,699	350,320	8,133	323,275	326,020
$2x10^{-7}$	100	3,664	768,227	22,906	758,767	884,295
$1x10^{-7}$	100	0	737,477	16,805	759,265	701,275
$9x10^{-8}$	100	0	42,725	2,971	84,351	4,013
$8x10^{-8}$	100	0	2,994	3,541	9,758	2,390
$7x10^{-8}$	100	0	1,814	6,147	2,072	1,847
$6x10^{-8}$	100	0	0	14,310	620	38
$5x10^{-8}$	100	0	0	22,436	0	37

Table I-1. Cancer Risk Cumulative Probability Distribution for AK Steel Middletown: By Emission Source for 50 kilometer Site

Risk Bin	Cumulative Probability[1]	Population Count				
		All Sources	MACT I Battery Emissions (charging, doors, lids, offtakes)	By-product Plant	MACT II	
					Pushing Fugitives	Quenching
4x10^{-8}	100	0	0	31,863	0	20
3x10^{-8}	100	0	0	53,121	0	22
2x10^{-8}	100	0	0	268,276	0	25
1x10^{-8}	100	0	0	523,986	0	14
9x10^{-9}	100	0	0	182,751	0	4
8x10^{-9}	100	0	0	229,097	0	7
7x10^{-9}	100	0	0	239,592	0	1
6x10^{-9}	100	0	0	273,237	0	2
5x10^{-9}	100	0	0	342,194	0	6
4x10^{-9}	100	0	0	73,136	0	2
3x10^{-9}	100	0	0	1,506	0	4
2x10^{-9}	100	0	0	0	0	0
1x10^{-9}	100	0	0	0	0	1
9x10^{-10}	100	0	0	0	0	0
8x10^{-10}	100	0	0	0	0	0
6x10^{-10}	100	0	0	0	0	0
5x10^{-10}	100	0	0	0	0	0
4x10^{-10}	100	0	0	0	0	1
3x10^{-10}	100	0	0	0	0	0
		2,327,420	2,327,429	2,327,422	2,327,430	2,327,424

[1] Determined using the formula:

(Number of people per source/ total number of people around facility) x 100 = cumulative probability

For example:

(22 people from "All Source" column / 2327420 (total population)) x 100 = .0009

(22 + 620 / 2327420) x 100 = .02758 , or .03 after rounding.

The probability for each risk bin assumes a 70-year exposure duration

Table I-2. Cancer Risk Cumulative Probability Distribution for AK Steel Ashland:
By Emission Source for 50 kilometer Site

Risk Bin	Cumulative Probability	Population Count				
		All Sources	MACT I Battery Emissions (charging, doors, lids, offtakes)	By-product Plant	MACT II	
					Pushing Fugitives	Quenching
6x10^{-4}	0.000	0	0	0	0	0
5x10^{-4}	0.002	8	0	0	0	0
4x10^{-4}	0.01	31	0	0	0	0
3x10^{-4}	0.02	58	0	0	0	0
2x10^{-4}	0.07	193	8	0	27	0
1x10^{-4}	0.27	774	58	1	71	4
9x10^{-5}	0.40	545	19	1	24	12
8x10^{-5}	0.55	591	27	3	38	19
7x10^{-5}	0.74	733	44	3	69	19
6x10^{-5}	1.04	1,223	62	8	127	47
5x10^{-5}	2	2,254	186	9	262	58
4x10^{-5}	3	4,105	383	27	699	136
3x10^{-5}	5	8,152	1,217	127	1,732	364
2x10^{-5}	8	12,389	3,825	546	5,172	1,450
1x10^{-5}	19	43,467	18,315	1,758	18,686	19,177
9x10^{-6}	21	10,209	2,765	474	2,920	4,023
8x10^{-6}	23	7,317	1,606	327	1,522	1,502
7x10^{-6}	24	4,885	1,277	289	1,388	1,124
6x10^{-6}	26	4,884	1,503	351	2,053	1,651
5x10^{-6}	28	10,492	2,737	676	3,304	3,419
4x10^{-6}	32	16,799	4,274	1,330	8,127	9,939
3x10^{-6}	38	22,422	15,472	3,685	17,820	18,660
2x10^{-6}	57	74,561	36,989	7,174	39,087	41,328
1x10^{-6}	75	73,812	34,115	9,034	32,190	40,670

Table I-2. Cancer Risk Cumulative Probability Distribution for AK Steel Ashland: By Emission Source for 50 kilometer Site

		Population Count				
			MACT I Battery Emissions (charging, doors, lids, offtakes)	By-product Plant	MACT II	
Risk Bin	Cumulative Probability	All Sources			Pushing Fugitives	Quenching
9x10^{-7}	81	21,520	6,488	2,988	12,221	13,872
8x10^{-7}	87	24,886	8,257	3,257	18,103	21,080
7x10^{-7}	92	19,479	19,267	3,944	15,330	24,138
6x10^{-7}	97	18,629	19,374	7,218	26,534	23,648
5x10^{-7}	99	9,598	31,866	10,095	24,342	27,392
4x10^{-7}	100	3,878	28,495	15,900	31,649	50,207
3x10^{-7}	100	53	57,189	25,302	70,716	57,397
2x10^{-7}	100	0	87,770	27,877	58,871	34,493
1x10^{-7}	100	0	14,345	38,056	4,882	2,130
9x10^{-8}	100	0	21	15,285	0	0
8x10^{-8}	100	0	0	22,499	0	0
7x10^{-8}	100	0	0	27,202	0	0
6x10^{-8}	100	0	0	39,467	0	0
5x10^{-8}	100	0	0	40,750	0	0
4x10^{-8}	100	0	0	34,894	0	0
3x10^{-8}	100	0	0	40,476	0	0
2x10^{-8}	100	0	0	15,753	0	0
1x10^{-8}	100	0	0	1,168	0	0
9x10^{-9}	100	0	0	0	0	0
8x10^{-9}	100	0	0	0	0	0
7x10^{-9}	100	0	0	0	0	0
6x10^{-9}	100	0	0	0	0	0
5x10^{-9}	100	0	0	0	0	0
4x10^{-9}	100	0	0	0	0	0
3x10^{-9}	100	0	0	0	0	0
		397,947	397,954	397,954	397,966	397,959

Table I-3. Cancer Risk Cumulative Probability Distribution for Erie Coke: By Emission Source for 50 kilometer Site

Risk Bin	Cumulative Probability	Population Count				
		All Sources	MACT I Battery Emissions (charging, doors, lids, offtakes)	By-product Plant	MACT II	
					Pushing Fugitives	Quenching
$2x10^{-4}$	0	0	0	0	0	0
$1x10^{-4}$	0.002	6	0	0	0	0
$9x10^{-5}$	0.005	11	0	0	0	0
$8x10^{-5}$	0.01	22	0	0	0	0
$7x10^{-5}$	0.03	50	1	0	0	0
$6x10^{-5}$	0.06	101	5	0	0	0
$5x10^{-5}$	0.1	208	16	0	2	0
$4x10^{-5}$	0.3	501	67	0	16	0
$3x10^{-5}$	0.7	1,399	238	0	94	0
$2x10^{-5}$	2.1	4,826	1,157	0	623	0
$1x10^{-5}$	7.9	19,059	8,774	0	6,740	0
$9x10^{-6}$	9.1	4,238	1,928	0	1,333	0
$8x10^{-6}$	9.6	1,678	1,262	0	587	0
$7x10^{-6}$	10.1	1,531	903	0	562	0
$6x10^{-6}$	10.7	1,997	1,387	0	812	0
$5x10^{-6}$	12.8	6,949	2,679	0	3,087	0
$4x10^{-6}$	16.7	13,041	3,556	0	3,316	2
$3x10^{-6}$	24.0	24,462	8,782	1	5,783	779
$2x10^{-6}$	36.3	40,749	29,036	3	19,671	5,792
$1x10^{-6}$	48.4	40,426	39,830	5	32,970	17,539
$9x10^{-7}$	51.0	8,503	8,955	3	10,242	5,530
$8x10^{-7}$	52.9	6,628	6,507	3	12,934	7,179
$7x10^{-7}$	55.2	7,390	9,066	4	11,329	9,893
$6x10^{-7}$	56.9	5,851	13,016	11	9,337	12,780
$5x10^{-7}$	58.4	4,811	21,218	11	14,733	16,638
$4x10^{-7}$	63.4	16,748	17,265	16	24,843	24,738
$3x10^{-7}$	68.4	16,734	13,901	75	21,398	29,183
$2x10^{-7}$	75.3	22,835	22,887	352	19,990	41,201
$1x10^{-7}$	93.0	59,016	21,676	1,137	22,743	20,529
$9x10^{-8}$	94.5	4,898	4,444	404	5,509	4,233
$8x10^{-8}$	96.5	6,979	4,733	595	4,842	12,221

Table I-3. Cancer Risk Cumulative Probability Distribution for Erie Coke: By Emission Source for 50 kilometer Site

		Population Count				
			MACT I Battery Emissions (charging, doors, lids, offtakes)	By-product Plant	MACT II	
Risk Bin	Cumulative Probability	All Sources			Pushing Fugitives	Quenching
$7x10^{-8}$	99.1	8,481	11,178	849	5,894	5,317
$6x10^{-8}$	99.98	2,960	18,992	1,477	7,420	11,209
$5x10^{-8}$	100	71	33,563	2,615	16,771	6,363
$4x10^{-8}$	100	0	12,679	2,905	44,444	9,166
$3x10^{-8}$	100	0	13,424	6,663	18,255	29,859
$2x10^{-8}$	100	0	63	13,152	6,898	45,643
$1x10^{-8}$	100	0	0	23,318	0	17,389
$9x10^{-9}$	100	0	0	8,200	0	0
$8x10^{-9}$	100	0	0	9,770	0	0
$7x10^{-9}$	100	0	0	13,530	0	0
$6x10^{-9}$	100	0	0	16,009	0	0
$5x10^{-9}$	100	0	0	14,580	0	0
$4x10^{-9}$	100	0	0	19,804	0	0
$3x10^{-9}$	100	0	0	30,143	0	0
$2x10^{-9}$	100	0	0	25,425	0	0
$1x10^{-9}$	100	0	0	23,956	0	0
$9x10^{-10}$	100	0	0	8,686	0	0
$8x10^{-10}$	100	0	0	4,548	0	0
$7x10^{-10}$	100	0	0	4,782	0	0
$6x10^{-10}$	100	0	0	7,775	0	0
$5x10^{-10}$	100	0	0	17,525	0	0
$4x10^{-10}$	100	0	0	24,441	0	0
$3x10^{-10}$	100	0	0	32,782	0	0
$2x10^{-10}$	100	0	0	17,620	0	0
$1x10^{-10}$	100	0	0	5	0	0
		333,159	333,188	333,180	333,178	333,183

Table I-4. Cancer Risk Cumulative Probability Distribution for Tonawanda:
By Emission Source for 50 kilometer Site

Risk Bin	Cumulative Probability	Population Count				
		All Sources	MACT I Battery Emissions (charging, doors, lids, offtakes)	By-product Plant	MACT II	
					Pushing Fugitives	Quenching
$2x10^{-4}$	0	0	0	0	0	0
$1x10^{-4}$	0.0003	3	0	1	0	0
$9x10^{-5}$	0.0007	5	0	0	0	0
$8x10^{-5}$	0.001	5	0	0	0	0
$7x10^{-5}$	0.002	6	0	0	0	0
$6x10^{-5}$	0.002	6	0	0	0	0
$5x10^{-5}$	0.003	6	1	1	1	0
$4x10^{-5}$	0.003	8	8	2	9	0
$3x10^{-5}$	0.005	19	10	2	11	0
$2x10^{-5}$	0.14	1,580	10	9	11	0
$1x10^{-5}$	2.1	23,168	1,586	32	1,587	0
$9x10^{-6}$	2.5	4,196	1,193	6	1,202	0
$8x10^{-6}$	2.7	2,906	458	2	450	0
$7x10^{-6}$	3	2,868	404	2	414	0
$6x10^{-6}$	3	5,459	573	3	600	0
$5x10^{-6}$	5	15,208	2,156	5	2,286	2
$4x10^{-6}$	7	25,970	7,160	5	7,372	5
$3x10^{-6}$	13	68,433	10,606	8	10,488	293
$2x10^{-6}$	27	164,621	40,231	891	41,534	5,522
$1x10^{-6}$	50	270,884	89,040	2,453	90,157	17,653
$9x10^{-7}$	54	40,476	22,168	1,070	21,662	5,308
$8x10^{-7}$	58	54,364	39,361	1,845	40,841	7,022
$7x10^{-7}$	62	43,377	33,579	3,234	33,806	13,375
$6x10^{-7}$	66	45,357	66,881	4,003	68,724	25,905

Table I-4. Cancer Risk Cumulative Probability Distribution for Tonawanda:
By Emission Source for 50 kilometer Site

Risk Bin	Cumulative Probability	Population Count				
		All Sources	MACT I Battery Emissions (charging, doors, lids, offtakes)	By-product Plant	MACT II	
					Pushing Fugitives	Quenching
5x10^{-7}	74	94,581	131,746	7,485	134,163	50,382
3x10^{-7}	90	94,783	125,584	21,626	126,578	256,503
2x10^{-7}	97.51	87,016	177,478	90,836	177,821	260,274
1x10^{-7}	99.75	26,114	151,103	118,912	148,674	171,481
9x10^{-8}	99.95	2,308	23,133	31,009	22,872	29,311
8x10^{-8}	99.998	545	29,826	50,468	30,469	51,356
7x10^{-8}	100	18	28,458	88,861	26,910	30,838
6x10^{-8}	100	0	23,383	99,893	23,276	33,394
5x10^{-8}	100	0	18,225	64,339	17,527	38,589
4x10^{-8}	100	0	11,713	97,962	11,266	29,575
3x10^{-8}	100	0	3,674	112,573	3,429	17,563
2x10^{-8}	100	0	0	206,410	0	9,948
1x10^{-8}	100	0	0	110,346	0	0
9x10^{-9}	100	0	0	14,626	0	0
8x10^{-9}	100	0	0	15,576	0	0
7x10^{-9}	100	0	0	7,972	0	0
6x10^{-9}	100	0	0	1,703	0	0
5x10^{-9}	100	0	0	30	0	0
4x10^{-9}	100	0	0	0	0	0
3x10^{-9}	100	0	0	0	0	0
2x10^{-9}	100	0	0	0	0	0
1x10^{-9}	100	0	0	0	0	0
		1,163,322	1,163,315	1,163,320	1,163,313	1,163,296