Evaluation of Cumulative Risk from an Iron Foundry

Control #58

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ABSTRACT

Hazardous air pollutant (HAP) regulations in Wisconsin required a cumulative impact analysis for an existing iron foundry. The combined inhalation risk was not allowed to exceed 10×10^{-6}. A comprehensive emissions inventory was compiled for 16 individual HAP released from 82 foundry operations, emergency generators and natural gas combustion. Evaluated HAP included benzene, formaldehyde, polychlorinated dibenzo-p-dioxin, polychlorinated dibenzofurans, trace metals and polyaromatic hydrocarbons. To simplify the analysis, emissions from each discharge point were reduced to an equivalent quantity of benzene emissions, referred to as "TEQ as Benzene". The equivalent emissions were calculated using a ratio of the unit risk value for each HAP and that of benzene. Downwind air pollutant concentrations were predicted using the ISC3 dispersion model. The cumulative risk was then estimated by applying the unit risk value of benzene to the predicted concentrations. The analysis verified that the estimated cumulative risk due to foundry operations was less than the 10×10^{-6} requirement.

INTRODUCTION

Hazardous air pollutant (HAP) regulations in Wisconsin under Chapter NR 445, Wisconsin Administrative Code, require emissions of known or suspected carcinogens to be controlled using methods determined to represent either Lowest Achievable Emission Rate or Best Available Control Technology. In lieu of controlling the emissions, a facility can demonstrate that the combined inhalation risk due to all discharges is less than 10×10^{-6}.

This cumulative risk analysis requires the following steps:

1. Development of an inventory of HAP emissions.
2. Dispersion modeling analysis to determine off-site HAP concentrations.
3. Estimation of inhalation risk due to each HAP.
4. Calculation of combined risk from all HAP.

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The inventory, modeling and risk estimation procedures used for an iron foundry are presented. These procedures were reviewed and approved by the Wisconsin Department of Natural Resources prior to issuing an air quality permit to an iron foundry.[1, 2, 3]

HAP INVENTORY DEVELOPMENT

A comprehensive emissions inventory was compiled for 16 HAP released from 82 foundry operations including emergency generators and natural gas combustion. The foundry produces grey and ductile iron castings. Operations include a cupola for iron melting, and nine casting production lines using green sand molds, and both coldbox and warmbox cores. In a typical year, approximately 700,000 tons of iron are produced. All operations are equipped with state-of-the-art air pollution control systems. The cupola is equipped with an incineration-dry injection-baghouse control systems. All dust generation points are equipped with pulse-jet baghouse control systems.

Evaluated HAP only included those known or suspected human carcinogens with unit risk factors. These HAP included the following:

Arsenic
Beryllium
Cadmium
Nickel
Benzene
Formaldehyde
Polychlorinated dibenzo-p-dioxin (PCDD)
Polychlorinated dibenzofurans (PCDF)
Benz (a) anthracene
Benzo (a) pyrene
Benzo (b) fluoranthene
Benzo (k) fluoranthene
Indeno (123-cd) pyrene
1,4 - Dichlorobenzene
Hexachlorobenzene
Dibenz (a,h) anthracene

For emission estimates, the following resources were used:

- Recent construction permit applications and Wisconsin annual emission inventory reports.
- USEPA, *Compilation of Air Pollutant Emission Factors, Fifth Edition, January 2003.*
- USEPA, *Factor Information Retrieval (FIRE) Data System, Version 6.23,October 2000.*

- Compliance stack tests for HAP emissions conducted at this foundry and similar facilities.

- Internal testing for HAP emissions conducted at this foundry and similar facilities.

The combined risk analysis included facility emissions which are typically exempt from regulation under the NR 445 regulations. These include operations subject to federal HAP control requirements, combustion of fossil fuels, laboratories, indoor fugitive sources, gasoline dispensing, and combustion of wood with good combustion technology.

This approach included emissions from the cupola iron melting and pouring/mold cooling operations, which are regulated under the Maximum Available Control Technology or MACT regulations for the control of hazardous air pollutants from iron and steel foundries under 40 CFR Part 63 Subpart EEEEE—National Emission Standards for Hazardous Air Pollutants for Iron and Steel Foundries, adopted April 22, 2004. Additionally, emissions were included from natural gas burning by space heating and drying ovens and distillate fuel burning by emergency electrical generators.

TOXIC EQUIVALENCY METHOD

There are several ways to estimate the cumulative risk.

One approach is to predict the maximum annual average concentrations for each HAP over a five-year period, determine the maximum risk for each HAP, and combine the maximum risk for all HAP. This approach is conservative since the maximum annual concentrations for each of the HAP may not occur at the same location or meteorological year.

A second method calculates the risk for each HAP at each location and meteorological year, then totals the risk at each location and year for all HAP. This method is cumbersome since a separate risk calculation would be required for each HAP, receptor and meteorological year, and the results for each receptor and year would need to be combined. The number of calculations required increases with number of HAP, modeling receptors and meteorological years. For this project, this method would require over 100,000 post-modeling calculations.

A simpler but equally effective approach to the second method is the use of toxic equivalents. This approach was presented to and approved by the regulatory staff of the Wisconsin Department of Natural Resources. For this method, the HAP emissions from each stack are converted into toxic equivalents, or an equivalent amount of a common HAP. In this case, benzene was used as the basis to convert the emissions of each carcinogen into an equivalent emission rate of benzene. The conversion was based on the ratio of the unit risk value of the HAP under evaluation and the unit risk value for benzene. The "TEQ as Benzene" were then totaled for each stack and used for the subsequent modeling analysis. Unit risk values were obtained from either the USEPA Integrated Risk Information System or the California Air Resources Board database.

For example, the unit risk value for formaldehyde is 1.3×10^{-5} $(\mu g/m^3)^{-1}$ and the unit risk value of benzene is 7.8×10^{-6} $(\mu g/m^3)^{-1}$. A formaldehyde emission rate of 1 lbs/hr is converted to a TEQ as Benzene by the following calculation:

$$\text{TEQ as Benzene} = 1 \text{ lbs/hr formaldehyde} \times (1.3 \times 10^{-5}) \div (7.8 \times 10^{-6}) = 1.67 \text{ lbs/hr}$$

Combined TEQ as Benzene emissions from the entire facility were 33.52 lbs/hr. Contributions to these emissions by HAP category are as follows:

Organic HAP	92.3%
Inorganic HAP	7.3%
Exempt HAP	0.3%

The exempt HAP are generated by the combustion of natural gas and diesel fuel.

Contributions to the emissions by individual HAP are as follows:

Benzene	56.5%
PCDD/F	26.3%
Formaldehyde	9.5%
Nickel	2.4%
Beryllium	2.0%
Arsenic	2.0%
Cadmium	0.7%
Exempt HAP	0.3%
Benzo (a) pyrene	0.1%
Other organic HAP	0.05%

DISPERSION MODELING PROCEDURES

For this analysis, the latest version of the Industrial Source Complex Short-Term Version 3 (ISC3) dispersion model was employed using the following assumptions:

1. Receptor elevations to account for variations in local topography.

2. Rural dispersion coefficients applicable to the facility location.

3. Regulatory model default options including calm correction, buoyancy induced dispersion, stack tip downwash, direction-specific downwash, final plume rise, default wind profile coefficients, and default vertical potential temperature gradients.

4. The facility layout and building dimensions. These were processed with the USEPA Building Profile Input Program (BPIP) model to calculate building direction-specific data. The downwash data was incorporated into the ISC3 model.

5. Five years of surface and upper air meteorology data provided by the regulatory agency.

6. A receptor grid beginning at the property boundary and extending to a sufficient distance to predict the maximum annual average concentration for entire facility.

7. Parameters for 20 separate stacks modeled as point sources.

8. Total TEQ as Benzene emissions from each stack.

HAP emissions from fuel combustion within the foundry were assumed to be captured by the production ventilation systems and exhausted through stacks. Emissions were distributed based on the exhaust flow rate of each stack.

COMBINED RISK ESTIMATE

The maximum annual average TEQ as Benzene concentration predicted for each meteorological year is presented summarized in Table 1.

Table 1 Predicted Annual Average Concentrations

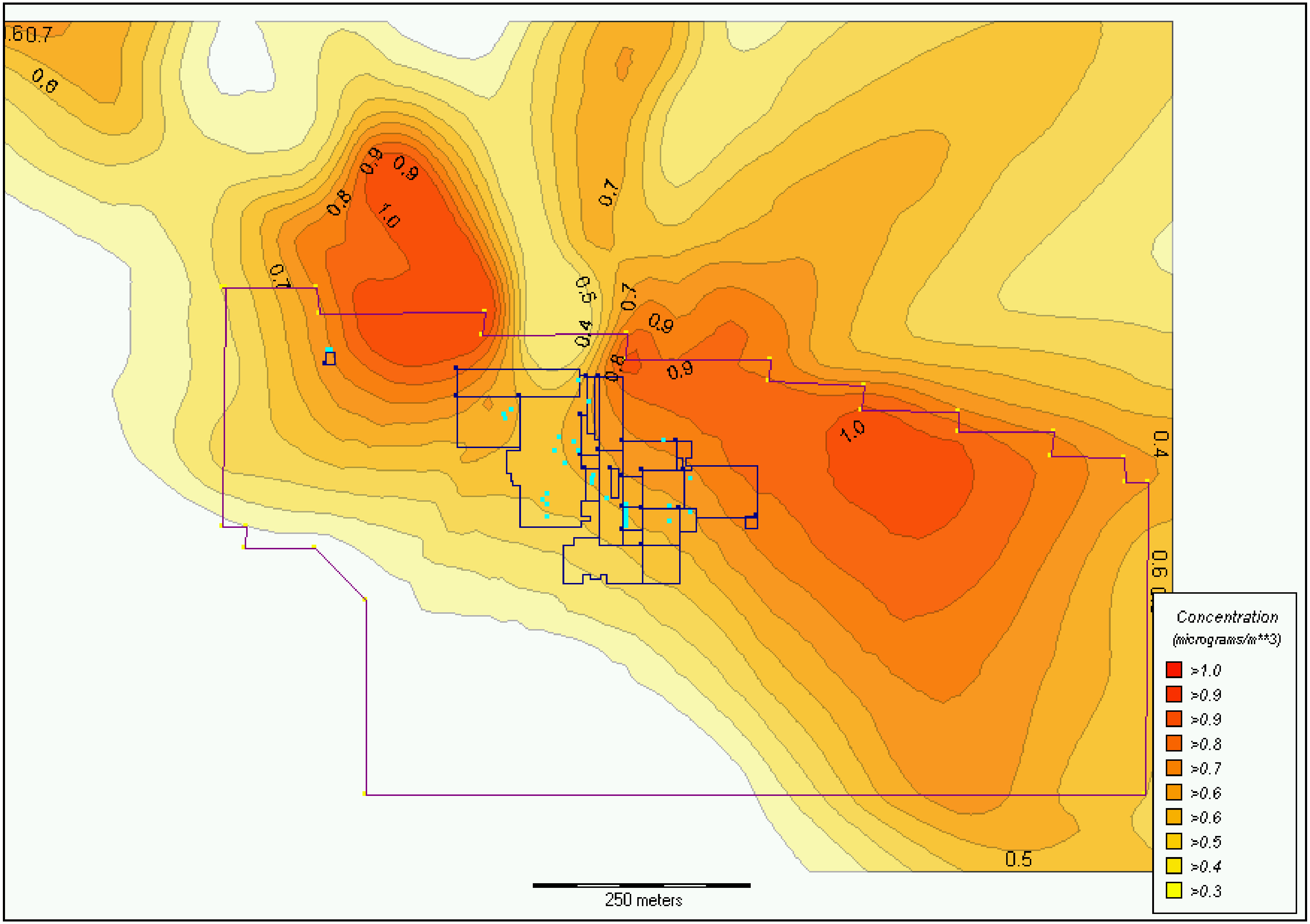
Hazardous Air Pollutant	*Meteorological Year*	*Maximum Concentration ($\mu g/m^3$)*
TEQ as Benzene	1	1.14
	2	1.24
	3	1.25
	4	1.01
	5	1.02

The predicted maximum annual average concentration was 1.25 ug/m^3. This concentration represents the combined impact of all HAP emissions. The unit risk value for benzene from the USEPA Integrated Risk Information System is 7.8×10^{-6} $(\mu g/m^3)^{-1}$. The estimated TEQ impact or cumulative risk is as follows:

$$\text{Cumulative Risk} = 1.25\ \mu g/m^3 \times 7.8 \times 10^{-6}\ (\mu g/m^3)^{-1} = 9.75 \times 10^{-6}$$

For meteorological year 3, annual average TEQ as Benzene concentrations were plotted into concentration contours. These are shown in Figure 1. The foundry building and stacks are in the center of the figure. The maximum off-site concentration occurs northwest of the facility, just beyond the property boundary.

Figure 1 - Predicted Annual Average TEQ as Benzene Concentrations (μg/m³)



CONCLUSIONS

As shown by this analysis, the maximum predicted combined inhalation risk was less than the 10×10^{-6} threshold under Wisconsin's NR 445 hazardous air pollutant regulations. It was concluded that the foundry met the risk-based compliance method and no further analysis for emissions control was necessary.

This predicted impact incorporates the following assumptions to assure the analysis generated a conservative estimate of the cumulative risk:

- Use of the concentration from the highest year of the 5-year analysis;
- Use of the concentration from the highest location among modeling receptors;
- Use of emissions based on maximum production capacity;
- Use of approved emission limits with a margin of safety over actual emissions; and,
- Use of the highest test results, even when some tests measured no detectable emissions.

REFERENCES

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KEY WORDS

hazardous air pollutants, HAP, risk, combined risk, cumulative risk, foundry, foundries, modeling, inventory, toxic equivalents, TEQ, TEQ as Benzene