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Outdoor Wood-Fired Boilers: A Synopsis for Urban Use

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Prepared for:

City of Cincinnati
July 7th, 2010

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Disclaimer

This brief report was conducted under the auspices of the Alliance for Risk Assessment (*ARA*), a consortium of three 501c3 non-profit organizations and a diverse Steering Committee of government and non-government institutions. Internal resources of Toxicology Excellence for Risk Assessment (TERA) were donated to the *ARA* and used to develop this report. Information about the *ARA*, its Steering Committee and projects can be found at www.allianceforrisk.org.

The authors welcome comments and further work in this area of environmental importance. All analyses are to be considered preliminary and subject to change pending the receipt of additional information.

Problem Formulation

Outdoor wood-fired boilers (OWBs), sometimes called outdoor wood furnaces, or outdoor hydronic heaters vary in size ranging from 115,000 Btu/hr up to 3.2 million Btu/hr. According to sales data collected by NESCAUM (2006), the size of the most commonly sold unit is 500,000 Btu/hr. Most residential OWBs are less than 1 million Btu/hr. OWBs are used for a variety of heating purposes, most often used to heat buildings ranging in size from 1,800 square feet to 20,000 square feet. Dimensions of an OWB typically fall within three to five feet wide, six to nine feet deep, and six to ten feet tall when including the height of the chimney. OWBs contain a firebox that ranges from 20 cubic feet up to 150 cubic feet. The furnaces are encased by a water jacket that is heated to 190º F. Most OWBs are not equipped with catalytic converters or secondary combustion, like those used in EPA approved indoor woodstoves. Data obtained from manufacturers by Schreiber et al. (2005) found OWBs have heating efficiencies ranging from 28 to 55 percent, with an average of 43 percent.

Unfortunately, the use of OWBs in urban settings has lead to numerous complaints of health hazards (Brunsman 2006).

In the absences of federal or state regulation, risk management of OWBs emissions in Ohio is the responsibility of local municipalities (OEPA, 2008). With sales trends that forecast growing popularity of OWBs as a residential home heating option, and local OWB use in a densely populated urban setting, the City of Cincinnati requested information from Toxicology Excellence for Risk Assessment (TERA) to help local policy makers select appropriate strategies to mitigate health risk. Thus, TERA conducted this screening level assessment of the potential health risks of OWBs emissions for the City of Cincinnati Office of Environmental Quality, prior to a possible regulatory action.

The National Academy of Sciences (NAS 2009) describes risk assessment as a process that needs upfront planning and scoping in order to be an effective tool in a risk management decision. The appropriate upfront planning and scoping in the case of OWBs relates to the fact that even when these units are operating correctly, some distance is needed between the unit and humans in the immediate vicinity in order to prevent serious health injuries from smoke inhalation. This is likely also true of other air breathing life forms and plants. What is also true, however, is that some low level of wood smoke can be tolerated without any, or perhaps without any significant, risk. This is because humans, even sensitive humans, and plants and animals often have sufficient defenses against chemical exposures that need to be overcome before toxicity ensues (Klaassen, 2007).

These two basic toxicology concepts (high enough exposures cause toxicity, but lower levels can be without risk) suggest that experimental animal studies and inadvertent human exposures can be used to develop safe levels of exposure for individual chemicals, or mixtures, in various environmental media (such as ambient air). Often, these safe levels are then compared with measured or modeled chemical concentrations in order to establish whether a given exposure might be considered safe, or whether such exposures might exceed the safe concentration and perhaps be associated with some health risk.

The usual comparison is a direct one. Simply dividing the measured or modeled concentration by the estimated safe level determines a hazard quotient, and if this hazard quotient is over 1, then a risk of health effects is presumed. If the hazard quotient is significantly over 1, then a risk of health effects is probable.

The development of a hazard quotient is considered to be a good tool to consider in upfront planning and scoping of potential hazards of OWBs, and is further briefly described in this report.

Trends in OWB Sales

With increasing utility prices, Outdoor Wood-fired Boilers (OWBs) are gaining popularity as a cheaper alternative for home heating. While OWB usage initially took root in rural areas, they are now beginning to appear in suburban and urban neighborhoods. Sales estimates collected by the Northeast States for Coordinated Air Use Management (NESCAUM, 2006) approximate the number of OWBs currently in use to be more than 155,000 as of 2005, on pace to reach 500,000 in 2010. Manufacturers report OWB sales continue to rise 25-50% annually.

NESCAUM (2006) estimated more than 13,000 OWBs are located in Ohio in 2005. The American Lung Association (2009) estimated at least 19,000 OWBs have been purchased in Ohio since 1995, with annual growth rate of 50%. According to NESCAUM (2006) estimates, Ohio has the fourth highest number of OWBs in the U.S.

Expected Exposures

As described more fully in NESCAUM (2006), wood smoke emitted from OWBs is comprised of a mixture of particulates (PM) and numerous gases, including carbon monoxide, nitrogen, sulfur oxides, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and chlorinated dioxins. Emissions will depend on the size of the fire chamber, the use of a catalytic converter, the type and quantity of fuel/wood being burned, and the available oxygen for combustion. Like natural gas furnaces, OWBs are designed to operate with varying intensity based upon the heating needs of the building. OWBs can be used to heat houses, shops, domestic hot water, swimming pools, greenhouses, driveways and spas. The multiple uses sometimes require year-round combustion. Engineered to prolong the life of the fuel, OWBs are able to burn in low temperature and oxygen deprived conditions, increasing particulate matter (PM) release (see Figure 1 and Table 1 for a comparison with other combustion sources). Summer time combustion contributes to smog, and can exacerbate allergy and asthma symptoms. Perhaps more troublesome is the increasing use of OWBs for incineration of non-wood materials, including household waste and construction debris. Designed to accommodate large wood-loads, the boilers have the capacity to burn many different materials. This practice can result in an unpredictable variety of pollutants with a broad range of health effects.

Due to relatively low stack heights, typically less than 10 feet, OWB emissions may not always be carried up above neighboring buildings. In rural conditions this is less problematic, since neighbors are generally further apart, but OWBs are appearing in urban settings with smaller lots. OWBs located in such areas can provide neighbors with irregular, but not infrequent, plumes of wood-smoke.

For example, evaluations of OWB output have reported PM levels ranging from 18 to 269 grams per hour (g/hr) (Valentini and Clayton 1998; New York 2005). In terms of concentrations, a screening level study conducted by NESCAUM (2006), measured ambient levels of $PM_{2.5}$ (particulate matter with a size of 2.5 microns in diameter or less) within 150 feet of an OWB. NESCAUM (2006) reported maximum $PM_{2.5}$ of 8,880 $\mu g/m^3$ (micrograms per cubic meter), periodic levels of greater than 1000 $\mu g/m^3$ and frequent values greater than 400 $\mu g/m^3$. Michigan Department of Environmental Quality constructed a model to evaluate the spatial distribution of $PM_{2.5}$ emissions. Assuming an 8 foot stack height, and an emission rate of 1 lb/hr, the model estimated maximum1-hour average ambient levels of approximately 1,000 $\mu g/m^3$ $PM_{2.5}$ within an 80 foot proximity of the stack, 500 $\mu g/m^3$ PM within 150 ft, and 250 $\mu g/m^3$ $PM_{2.5}$ within 200 ft (Figure 2; NESCAUM 2006). Particles of this size are small enough that closed doors and windows will not prevent them from entering a house (Washington State Department of Ecology, 2004). However, we did not find an estimate or measurement of indoor air $PM_{2.5}$ levels in a brief literature search.

Figure 1. Particulate Matter Emissions from OWBs (g/hr) Figure 5.1 of NESCAUM (2006)

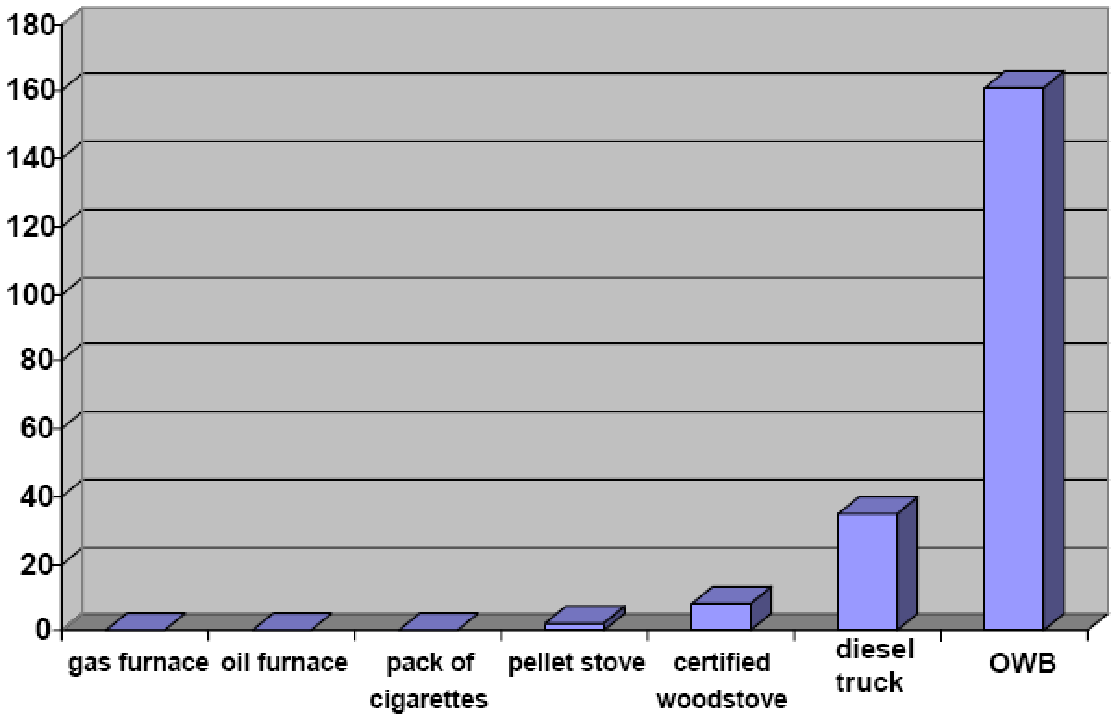


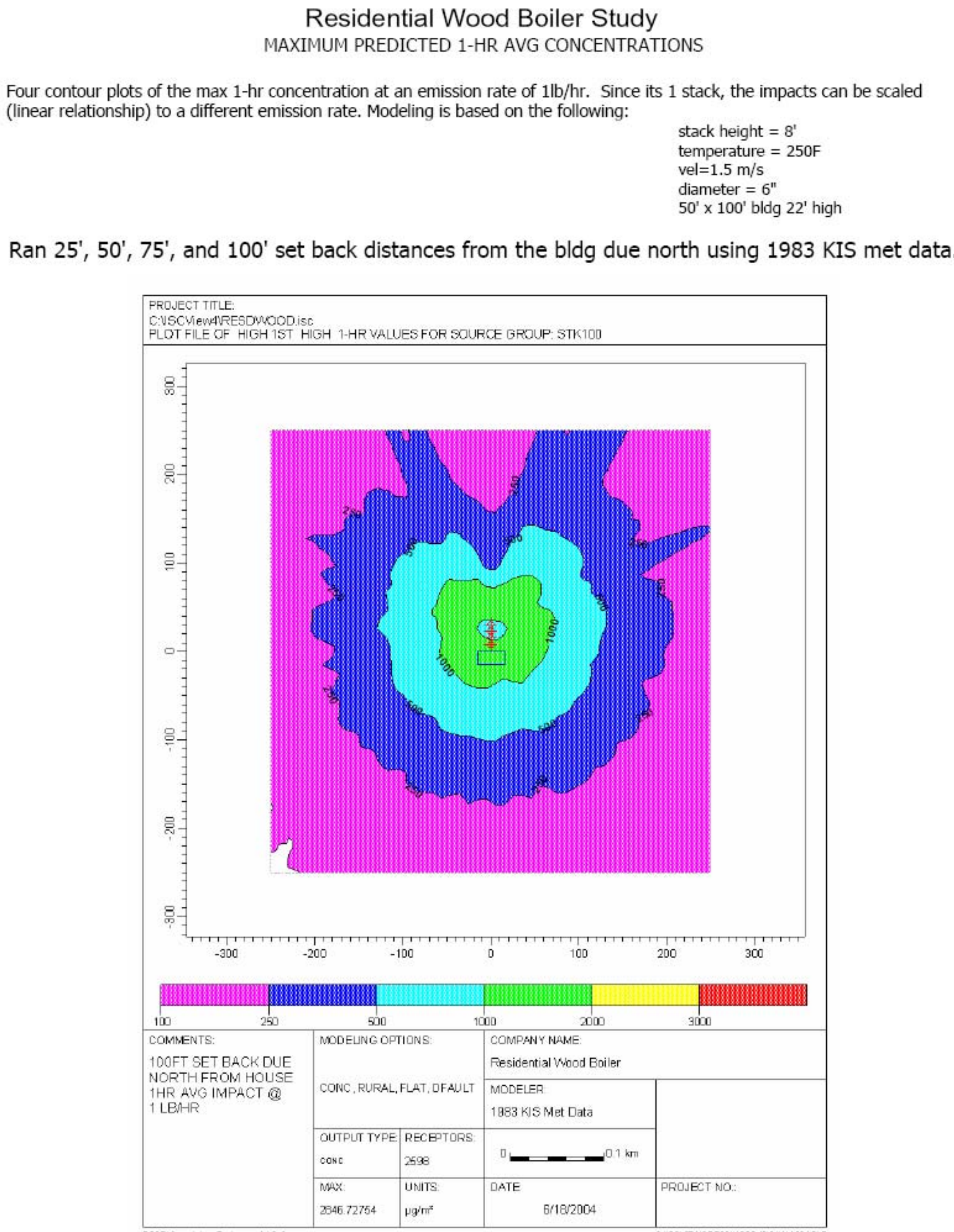
Table 1. Comparison of Emissions from Various Wood Combustion Units (Schreiber et al. 2005); (permission requested)

Type of Wood Combustion Unit	Particulate Matter, Average (grams per hour)	Polycyclic Aromatic Hydrocarbons, Average (grams per hour)
OWB	71.6 [ii]	0.96 [ii]
Conventional (non-EPA Certified) Wood Stove [i]	18.5 [iii]	0.36 [iv]
EPA Certified Catalytic Wood Stove [i]	6.2 [iii]	0.15 [iv]
EPA Certified Non-Catalytic Wood Stove [i]	6.0 [iii]	0.14 [iv]
EPA Phase-II Certified Woodstove [v]	4.1: EPA limit for catalytic woodstoves 7.5: EPA limit for non-catalytic woodstoves	Not Available

[i] Assumes 1.0 kg/hr burn rate.
[ii] Appendix A.
[iii] Houck, J. and Tiegs, P., *Residential Wood Combustion Technology Review, Volume 1. Technical Report*, EPA-600/R-98-174a. (1998).
[iv] Fisher, L., et al., *Long-Term Performance of EPA-Certified Phase 2 Woodstoves, Klamath Falls and Portland Oregon: 1998/1999.* EPA-600/SR-00-100 (2000).
[v] Subpart AAA-Standards of Performance for New Residential Wood Heaters, 40 CFR §§ 60.530-60.539b.

Figure 2. Michigan Department of Environmental Quality OWB Emissions Modeling (NESCAUM 2006).

Michigan DEQ created a hypothetical model of $PM_{2.5}$ emission distribution from an OWB with an 8 foot stack using meteorological data from K. I. Sawyer Airport. The model estimates the levels of particulate matter at various distances; 25, 50, 75, and 100 feet from the OWB**.**



Potential Health Risk

Particulate Matter

U.S. Environmental Protection Agency (EPA) has reviewed the toxicology of particulate matter (PM) over a number of years. The most recent evaluation occurred in 2006, summaries of which are found below and also on several websites. In brief, PM is associated with premature dealth in people with heart and/or lung disease, and EPA has set concentrations which will protect the public, including sensitive individuals, from these effects,

Specifically, EPA (2006) states that:

> The Clean Air Act requires EPA to set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, particle pollution (also known as particulate matter) is one of these. The Clean Air Act established two types of national air quality standards for particle pollution. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings.
>
> The nation's air quality standards for particulate matter were first established in 1971 and were not significantly revised until 1987, when EPA changed the indicator of the standards to regulate inhalable particles smaller than, or equal to, 10 micrometers in diameter (that's about 1/4 the size of a single grain of table salt).
>
> Ten years later, after a lengthy review, EPA revised the PM standards, setting separate standards for fine particles ($PM_{2.5}$) based on their link to serious health problems ranging from increased symptoms, hospital admissions and emergency room visits for people with heart and lung disease, to premature death in people with heart or lung disease.
>
> The 1997 standards also retained but slightly revised standards for PM_{10} which were intended to regulate "inhalable coarse particles" that ranged from 2.5 to 10 micrometers in diameter. PM_{10} measurements, however, contain both fine and coarse particles.
>
> EPA revised the air quality standards for particle pollution in 2006. The 2006 standards tighten the 24-hour fine particle standard from the current level of 65 micrograms per cubic meter ($\mu g/m^3$) to 35 $\mu g/m^3$, and retain the current annual fine particle standard at 15 $\mu g/m^3$. The Agency decided to retain the existing 24-hour PM_{10} standard of 150 $\mu g/m^3$. The Agency revoked the annual PM_{10} standard,

because available evidence does not suggest a link between long-term exposure to PM_{10} and health problems.

The Clean Air Act requires EPA to review the latest scientific information and standards every five years. Before new standards are established, policy decisions undergo rigorous review by the scientific community, industry, public interest groups, the general public and the Clean Air Scientific Advisory Committee (CASAC).

To express noncancer hazards the EPA often uses a calculation called the hazard quotient (HQ), which is the ratio between the concentration to which a person is exposed and the risk value or standard (EPA, 1998). In the case of OWB emissions, an HQ may be calculated by dividing the maximum ambient air levels estimated by Michigan DEQ of 1,000 $\mu g/m^3$ $PM_{2.5}$, 500 $\mu g/m^3$ $PM_{2.5}$, and 200 $\mu g/m^3$ $PM_{2.5}$ by the 24-hour fine particle standard of 35 $\mu g/m^3$. This results in HQs of 29 within 80 ft of the OWB, 14 within 150 ft, and 6 within 200 feet.

A value of the HQ equal to or less than 1 indicates that the exposure is not likely to result in adverse health effects. A value of the HQ greater than 1 indicates that the exposure is higher than the risk value, and adverse health effects might occur. However, because risk values incorporate protective assumptions to account for uncertainty, an HQ greater than a value of 1 does not necessarily indicate the likelihood of adverse effects. In contrast, values much greater than a value of 1 are more likely associated with adverse health effects.

Based on the $PM_{2.5}$ modeling data, the area within a 200 ft radius of the OWB experiences emission levels that are 6 fold, or greater, than the EPA's 24-hour health standard, indicating the potential for a health risk. Within 80 feet, the emission levels are 29 fold greater than the safe level, indicating that this potential health risk is more likely to occur.

Other Chemicals

Available resources did not permit an additional analysis of other chemical exposures. In brief, in addition to PM, and as more fully described by several investigators (e.g., NESCAUM, 2006), wood smoke contains many chemicals in a complex mixture of particles and gases. Many of these chemicals have been shown to produce acute and chronic toxicity at high enough concentration. For example, some of the gases in wood smoke include carbon monoxide, chlorinated dioxins, nitrogen and sulfur oxides, PAHs, and volatile organic compounds (VOCs).

The toxicity of several of these chemicals are well described in standard toxicology textbooks. For example, carbon monoxide can cause respiratory and cardiac effects because it competes with oxygen on for binding on hemoglobin, forming carboxyhemoglobin, a molecule that release oxygen more slowly. Nitrogen oxides cause pulmonary edema, bronchi constriction, and immunological effects. Several PAHs and dioxins are carcinogenic in animals and may cause cancer in humans (e.g., Klaassen et al, 2007).

Regulation of Outdoor Wood-Fired Boilers

Federal law does not regulate OWBs, and states have taken various approaches in regulation. In Ohio, public comments received in response to a draft state policy in February 2008 led OEPA to withdraw a proposed statewide rule to regulate OWBs. OEPA opted to defer to local municipalities to make regulation decisions based on local conditions. However, OEPA did update its incinerator rules to address the burning of non-wood materials. Under the new draft rule, use of “garbage, tires, rubber or plastic coated wire, materials containing plastic, materials containing rubber, creosote-impregnated waste materials, waste petroleum products, paint and paint thinners, chemicals, wall board, manure, animal carcasses, or asphalt products” would subject the owner to incineration rules, which would require the owner to obtain an operating permit from Ohio EPA, and demonstrate the OWB meets emissions limits through monitoring (Ohio EPA 2010).

Outside of Ohio, states have tried a variety of strategies to control OWB emissions, including:

Ban of Sales/Installation (NY)

The potential for health effects and nuisance to neighbors has led several counties in NY to institute an outright ban on OWBs (Schreiber et al. 2005).

Chimney Requirements (CT, VT, NH)

Several states have chimney height requirements. Some states have minimum heights, while others require the stack on the furnace to be higher than the roof line if the furnace is between 200 feet and 500 feet from the nearest neighboring home (Schreiber et al. 2005)

Setback Requirements (CT, VT, NY)

Some locations have implemented setback requirements. For example Vermont and Connecticut mandate installation of an OWB must be at least 200 feet from the nearest neighboring residence (Schreiber et al. 2005; NESCAUM 2006, Vermont 1997)

Emissions Standards (NH, WA)

In Washington, OWBs **“**must be shown to comply with an emission standard of 4.5 grams PM per hour before they can be offered for sale in the State of Washington” (Washington 1995, Schreiber et al. 2005).

In New Hampshire, OWBs “must meet the EPA Phase I emission limits. Effective April 1, 2010, all OWBs that are sold in the state must meet the Phase II emission limits” (New Hampshire 2010).

Density Restrictions/ Zoning Regulations (MA, NY)

The Town of Moreau, NY only permits OWBs on lots of 3 acres or greater (Schreiber et al. 2005). Setback minimums and chimney height restrictions often fall with zoning regulations.

No Burn Days (WA, MA)

Temporary bans on indoor and outdoor burning when the weather trends toward stagnant conditions, such as air inversions, which trap fine particle pollution emitted from our chimneys, cars, trucks, and other activities (Puget Sound Clean Air 2010).

The Town of Moreau specifies OWBs may only be operated between September 1 and May 31 (Schreiber et al. 2005).

Nuisance Laws (MA, CT)

Across the U.S. civil lawsuits have been filed against OWB operators under state nuisance laws. NESACUM (2006) reports civil suits in the New England area have often resulted in the complainant's favor.

Opacity Laws (MA)

OWBs have been challenged in Massachusetts on grounds of opacity ordinance violation. NESCAUM (2006) describes regulation of OWBs through opacity restriction to be inefficient and ineffective.

Public & Consumer Awareness (NY, NH)

Many purchasers of OWBs are unaware of the potential health consequences. Some communities have prepared public service announcements to deter the use of OWBs.

New Hampshire requires "any seller of an OWB is required to provide written notice to a perspective buyer on New Hampshire's law. The written notice must be signed and dated by the buyer and seller, include specific information on the OWB purchased, and be kept on file by the seller for at least three years" (New Hampshire 2010).

Permitting Requirements (NY)

Some municipalities have opted to require a permit for operation of an OWB. Permits often specify other performance standards required for legal operation (Schreiber et al. 2005).

Unique Cincinnati Features

Several attributes of the Cincinnati area are relevant to a discussion of OWBs. These include:

Low Wind Speeds – The Cincinnati area is in the Department of Energy's lowest category for wind energy potential. These low average wind speeds mean that air contaminants tend to disperse less rapidly than in areas that have average or high wind speeds.

Hilly Terrain – The Cincinnati area includes many locations with steep slopes. This increases the chances that a nearby receptor will be at a higher elevation than the top of an OWBs smokestack, and will therefore experience a greater concentration of air contaminants than a receptor at a lower elevation.

High Asthma Rates – Rates of asthma and other respiratory conditions fluctuate by neighborhood in Cincinnati, and substantially exceed the national average in some neighborhoods. This increases the chance that an especially sensitive individual will be among the nearby receptors of OWB emissions.

Poor Air Quality – Cincinnati is a non-attainment or borderline attainment area for PM 2.5 and Ozone under the Clean Air Act. In addition, EPA modeling indicates that excess cancer risks due to inhalation of air toxics in the outdoor air range from 3 per 100,000 to more than 20 per 100,000. These background levels of exposure to air pollution may make individuals more sensitive to the additional burden imposed by a nearby OWB.

Multiple Sources – Many Cincinnati neighborhoods are in close proximity to manufacturing industries that may have intermittent emissions of airborne chemicals. These emissions may meet single source emission standards but have synergistic adverse effects when combined with the high local concentrations of chemicals near OWB smokestacks.

Multi-Family Housing – There is a high concentration of apartment buildings in the city, with variable placement of air intake vents. Positioning of an OWB near an air intake vent for an adjacent apartment building has potential to spread toxic fumes to a large number of individuals.

Lack of Regulation – Current, Cincinnati has no regulations that require catalytic converters or other emissions cleansing devices for OWBs.

Quantification of the impacts of these factors on OWBs is beyond the scope of this report.

Acknowledgements:

The authors appreciate the endorsement of the Alliance for Risk Assessment (*ARA*) and the support of Larry Falkin of the City of Cincinnati Office of Environmental Quality in the initiation of this work. Internal resources of Toxicology Excellence for Risk Assessment (TERA) were used to develop this report.

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Statement of Purpose

Toxicology Excellence for Risk Assessment **(TERA)** is a non-profit, 501(c)(3) corporation organized for scientific and educational purposes. Our mission is to protect public health by developing and communicating risk assessment values, improving risk methods through research, and educating the public on risk assessment issues. Specific activities of **TERA** include:

- **establishing** high quality risk assessment values for human health and the environment through the Verifiable Estimates for Risk Assessment **(VERA)** program;
- **compiling** and distributing peer reviewed risk values to the international user community through the International Toxicity Estimates for Risk **(ITER)** database;
- **sponsoring** expert **peer review** of risk values;
- **improving** the underlying methods for human and ecological risk assessment through **research** and publication;
- **educating** diverse groups on risk assessment issues, through training courses, scientific support and the State Hazard Evaluation Lending Program **(State HELP)**;
- **facilitating** improved risk assessment and **management decisions** among industry and government groups through informed and neutral guidance.

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