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Wood Burning and Its Impacts on Human Health and Ambient Air Quality

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INTRODUCTION

The Broome County Environmental Management Council (EMC) is providing this white paper in its capacity as an advisory board to County government. The paper provides a summary of research conducted by EMC members pertaining to the impacts of wood smoke on human health and air quality. This research was prompted by complaints by residents living near Outdoor Wood Boilers (OWB) and the wide-ranging legislative approaches that municipalities have taken to address these complaints. The EMC is concerned about the impacts to air quality and human health associated with wood burning, particularly due to emissions by devices that have no regulatory oversight whatsoever.

The goal of this paper is to encourage a proactive stance when addressing the health and air quality issues resulting from burning wood fuel. Indoor woodstoves must meet standards established by the US Environmental Protection Agency (EPA), but other wood burning devices (including OWBs) do not have similar regulations. Further, the physical processes that determine wood smoke dispersion are not adequately considered in proposed air quality regulations, many of which are device-specific, exempting new designs from performance-based regulation. As the popularity of wood as an affordable energy source grows, and new technology is developed, proactive regulatory management is essential to avoid potential negative impacts on air quality. This paper provides an overview of this problem and pertinent scientific information, discusses the problems with current wood burner technology and regulatory oversight, and offers proposals for future regulation and incentives for advancing wood burner technology.

BACKGROUND

Recent increases in the cost of oil-based energy supplies have generated a renewed interest in alternative energy sources, with bio-fuels receiving increased scrutiny as a viable alternative. Wood, the most readily available of these, is domestically produced and can help to lower dependence on foreign energy supplies. In addition, wood is essentially "carbon-neutral", which is important when considering the issue of global climate change. Unfortunately, despite these benefits and its popularity, wood is much dirtier than other fuels, such as fuel oil, natural gas and propane.

In early American history, the population was largely dependent on wood as a primary fuel source. As technology advanced, wood use declined as it was replaced by coal and, more recently, oil, a relatively cleaner fuel with less airborne pollutants. Over this time period, life expectancy increased and respiratory disease decreased. The association between improved health and the use of a cleaner fuel source is unlikely to be a coincidence. With the increasing popularity of wood as an alternative fuel source and improved knowledge regarding the health impacts of wood smoke, it is essential to ensure that wood burning technologies, new and existing, maintain a high standard of air quality for the protection of human health and the environment.

WOOD: THE ORIGINAL BIOFUEL

Wood, a solid fuel, is chemically more complicated than liquid or gas fuels. Composed principally of chains of cellulose, wood breaks down into a multitude of other organic compounds as it is burned, each of which requires a unique fuel-air mixture for optimal combustion. Burning large pieces of wood also limits the surface area, inhibiting the mixing of the wood and oxygen. While wood pellets vastly improve the fuel/air ratio, the chemical complexity of the fuel remains. Therefore, wood is extremely difficult to burn at the efficiency necessary to eliminate its undesirable smoke by-products. Conversely, gaseous fuels (i.e. natural gas and propane) are chemically less complex and are easily mixed with air at the proper fuel/air ratios to obtain clean combustion.

HEALTH EFFECTS OF WOOD SMOKE

Wood smoke is a serious pollutant, no healthier than tobacco smoke. It contains particulate matter (PM), carcinogenic polycyclic aromatic hydrocarbons (PAH), and sometimes dioxins. PM impact on human health is well documented and contributes to several diseases including asthma, bronchitis, obstructive lung disease, cancer and autoimmune disorders. Due to this growing volume of data, the EPA proposed tightening the 24-hour air quality standard for smoke particulate matter (PM) from the current 65 micro-grams per cubic meter ($\mu g/m^3$) to 35 $\mu g/m^3$. According to a 2007 paper by Brown and others, “An Assessment of Risk from Particulate Released from Outdoor Wood Boilers”, exposure to PM concentrations as low as 20 $\mu g/m^3$ for durations as short as two hours causes a significant reduction in respiratory capacity in healthy adults. Young children and the elderly are at even greater risk of respiratory distress. In a 2007 report, “Dispersion Modeling Assessment of Impacts of Outdoor Wood Boiler Emissions in Support of NESCAUM’s Model Rule”, the New York State Department of Environmental Conservation (DEC) Division of Air Resources notes that the statewide background level of PM concentration from all sources is 15 $\mu g/m^3$, strongly suggesting a need for technology that can minimize the adverse impacts of wood smoke on air quality and human health, particularly if wood continues to be an increasingly attractive alternative to cleaner, conventional fuels.

CURRENT TECHNOLOGY STATUS

The Arab oil embargo drove up oil prices in the 1970’s, triggering a revival of wood use, particularly for home heating. Relatively poor heating performance and excessive smoke production led to the development of wood stove regulations by the EPA. These required the production of wood stoves with approximately 70% heating efficiency and less than 7.5 grams of PM emitted per hour. Wood stove installations with catalytic converter technology on their exhaust stacks are even cleaner and more efficient. More recently, pellet stoves that use pellets of wood fuel made from recycled wood by-products (i.e. wood chips and saw dust) have been developed, providing an incremental improvement over past wood burning technologies.

A relatively new device, the Outdoor Wood Burner (OWB), or Outdoor Hydronic Heater (OHH), is gaining both popularity and notoriety. This standalone product, that resembles a small storage building with an attached chimney, uses a large combustion chamber in which whole logs up to four feet in length may be placed. A large water jacket surrounding the combustion chamber absorbs heat from the wood fire and the heated water is pumped underground to a home or another building to provide heat. The building’s thermostat provides a signal to the OWB’s electronics that closes a damper to minimize air intake when peak heat demand is not required. When the damper is closed, the fire smolders but never goes out, and very large quantities of PM are produced. The water jacket surrounding the combustion chamber also cools (quenches) the fire by drawing away much of the heat required by the fire to burn efficiently, even during times of peak demand when adequate air is being supplied.

According to a 2006 report from the Northeast States for Coordinated Air Use Management (NESCAUM), "Assessment of Outdoor Wood-fired Boilers", tests show that, on average, OWBs produce forty (40) times as much PM as an EPA-certified wood stove. Further, the efficiency of the basic OWB is in the range of 30-40%, roughly half that of EPA-certified wood stoves (60-80%), suggesting that an OWB requires twice as much fuel to produce the same amount of heat. Efficiency is even further reduced by potential heat losses from transporting the heated water from the OWB to the building. Depending on these losses, the overall system efficiency of an OWB installation may be no better than a traditional fireplace (about 25% efficient).

Studies have also shown the intensity of PM concentrations in the vicinity of an operating OWB. NESCAUM measurements of PM concentrations 100 feet from an OWB range from 182 to 807 $\mu g/m^3$. Simulations by the DEC, documented in their 2007 report, suggest that PM concentrations may not meet the EPA air quality standard until approximately 500 feet from the OWB, under marginally unstable atmospheric conditions. Therefore, inefficient wood burner design contributes to unacceptable air quality, in addition to increase wood demand (ultimately driving up fuel wood prices) and adverse impacts on forested ecosystems from unsustainable levels of wood use.

WOOD SMOKE DISPERSION

Dispersion processes that dilute wood smoke concentrations are extremely complex, causing safe distances from OWBs (or other smoke sources) to vary considerably. Stable atmospheric conditions, such as clear nighttime skies, overcast days, and low wind speeds, inhibit smoke dispersion, conceivably causing unsafe concentrations at distances of 1000 to 1750 feet from a typical source, according to analysis by Corbeau Science & Technology (2007). The smoke concentrations measured by NESCAUM were recorded on days with average (moderately stable) atmospheric conditions. Local topography, tree cover, chimney height and local building density can also influence the dispersion of a smoke plume.

Additionally, Corbeau showed that multiple wood burning devices within a region will significantly impact background PM concentrations, resulting in poorer air quality than a similar region containing fewer, and/or more efficient wood burners. The DEC simulations noted in the previous section did not account for these variables, looking at smoke from only a single OWB under average atmospheric conditions. The statewide background PM concentration of 15 $\mu g/m^3$ in NY matches the US EPA annual average concentration standard. Operating multiple wood burning devices within a single neighborhood will virtually guarantee that annual average EPA PM standard is violated.

CURRENT REGULATORY OVERSIGHT

To minimize the negative impacts of OWBs, a number of municipalities have introduced regulations on their placement and design. Standard clauses in OWB ordinances require setbacks of 50 to 350 feet from neighboring buildings, that the parcel be a minimum of 3 acres, and that the chimney be higher than the neighboring buildings' rooflines. It is notable that an OWB at the center of a ten-acre parcel is only 330 feet from the property line. The issues addressed in this paper show the technical complexity of this topic, likely outside the range of expertise found on a typical municipal government's work force. Therefore, setback requirements and chimney stack heights are based on recommendations by OWB manufacturers who have not provided testing to validate the recommendations.

The DEC uses opacity standards to monitor problem sites. However, these do not correlate with unsafe smoke concentrations. Opacity, essentially the amount of light blocked by a smoke plume, is a very rough measurement of the PM concentration. New York air regulations (NYCRR Section 211.3) state that “no person shall allow any air contamination by any material having an opacity equal or greater to 20% (6 minute average) except for one continuous 6-minute period per hour of not more than 57% opacity”. In early July 2002, Quebec wild fires, in conjunction with weather conditions in northeastern North America, raised the PM concentrations in Philadelphia to a level in the range of 300 to 600 $\mu g/m^3$. This level is barely high enough to be smelled by some individuals and will not violate the NY opacity rule, but it is an order of magnitude greater than the current EPA PM standard.

In light of this data, none of these regulations provide adequate protection of the public’s air quality. Perhaps human physiology may be a better measurement of unsafe PM concentrations as complaints of nauseating fumes, headaches, burning eyes, and sore throats are common in the vicinity of unhealthy smoke concentrations. These sensory responses may be a warning to evacuate unsafe areas. At least 16 states have petitioned the EPA to establish OWB emission standards, and the list of municipalities banning the OWB outright is growing.

PROPOSED REGULATIONS

NESCAUM published their “Model Regulation for Outdoor Hydronic Heaters” in 2007 which proposes chimney height, setback, and emission standards for commercial and residential OWB installations. The proposed setback is 500 feet from adjoining properties based on the DEC simulations and the proposed chimney height regulation is “5 feet higher than any building roof structure within 150 feet of the installation”. The model regulation also includes (Phase II) emission standards of 15 grams/hr for residential installations, and 20 grams/hr for commercial installations, which do not meet the current EPA standard for indoor woodstoves. The regulation also proposes certification testing of all OWB products to ensure that the emission regulations are met.

In addition there are bills proposed in the NYS Assembly (A01982) and Senate (S3833) to regulate OWBs. These include setback regulations of 700 feet from schools and hospitals and only 200 from neighboring residences. They do not dictate any specific chimney height requirement, but propose mandating an emission standard that meets or is more stringent than the EPA indoor woodstove requirement. It is interesting that a distinction is made for setbacks with respect to schools and hospitals; it is unclear why additional air quality protection is required when at a hospital or school than when at home. On average, people spend more time at home than at these institutions, so the opportunity for long-term exposure is greater at home.

As outlined in this paper, these proposed regulations are based on relatively simplistic conditions, including nominal weather and dispersion characteristics, specific terrain type, and assuming only a single OWB within a neighborhood. With increased wood burning and the potential for new wood burning products in the future, more proactive and aggressive regulations considering all factors is necessary.

LOOKING TO THE FUTURE

Returning to wood fuel, a domestic energy source that is also carbon-neutral, may provide several economic, social and environmental advantages, assuming that the sustainable use of wood resources occurs and state-of-the-art technology to address air quality issues is embraced. When developing wood burning technology such as an OWB or other device, promoting sustainable use of the resource and minimizing adverse impacts to the environment should be a priority. The OWB in its current technological form is not an environmentally responsible choice as a wood burner due to inadequate efficiency and emissions production when compared to other fuel burning technologies. **Therefore, any wood burning device on the market should employ technology that ensures performance standards exceeding those of EPA-certified wood stoves, requiring heating efficiencies on the order of 80% and PM production levels of less than 7.5 grams/hour.**

In the meantime, short-term goals should be as follows:

1. Conserve the wood resources (or any other fuel) by minimizing the heat load demand of a dwelling. There is no better investment than insulation when it comes to reducing energy costs. With the current global demand for energy in all its forms, revision of the typical building code's standard 6-inch wall requirement is long overdue.

2. Construct buildings, or install wood-based heating systems, with adequate thermal heat storage capacity so that extreme temperature swings are minimized. This will also help reduce heat loss from the building or home.

3. Manufacturers of wood burning equipment should design combustion chambers that maximize the amount of heat produced per pound of wood consumed to ensure proper air supply at all times and optimal temperatures, both of which support optimal combustion. High-efficiency heat exchangers should be utilized to extract heat from the combustion chamber for use in building heating.

4. Use high quality, seasoned and dry wood, in small pieces for larger surface area and optimal fuel/air ratios needed for efficient combustion (partly why the new pellet stoves are more efficient than wood stoves). Wet or unseasoned wood does not burn efficiently because much of the combustion heat is lost due to quenching caused by the evaporation of the wood's water content.

5. When using a wood burner not located within the building being heated, minimize the distance between the device and the building to lower losses associated with transporting the heat. Proper insulation of these heat energy 'pathways' can improve the system-wide efficiency. However, placing a device too close to a building can cause an adverse impact on the dispersion of wood smoke. As with many engineering issues, there are design trade-offs.

6. Provide tax-based incentives (similar to those for solar electric and hot water systems) to promote the use of cleaner wood burning technologies, including incentives to help upgrade existing systems to a cleaner technology.

In the long term, consumer products that could clean the effluent of a wood burning device on a greater scale then the current catalytic devices found on state-of-the-art wood stoves would be highly desirable.

Perhaps with funding and ingenuity, a simplified stack scrubber could be made available and affordable for the typical household. This product would be a large benefit for protection of air quality, should wood become a more significant energy source. However, today's wood burning technology, like the OWB in its current form, does not constitute an acceptable technology when environmental and health factors are seriously considered.

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