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Two-Stroke Engines in Landscape Maintenance: A Growing Public Health Problem

Erica Walker, MA, Doctoral Candidate
Harvard School of Public Health
401 Park Drive
Boston, MA 02115

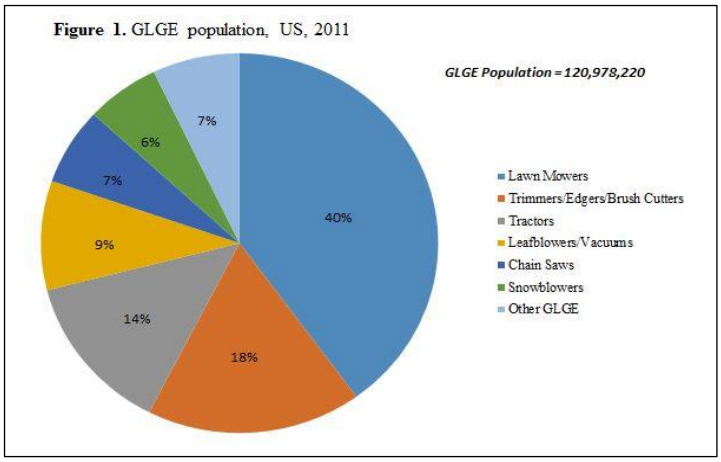
Jamie Banks, PhD, MS
Quiet Communities, Inc.
PO Box 533
Lincoln, MA 01773
jlbanks@quietcommunities.org

ABSTRACT

The home town of acoustic pioneers, Richard Bolt and Robert Newman (founders of Bolt, Beranek, and Newman), was recently the site of a pilot study to characterize an under-recognized source of pollution and noise: the two-stroke gasoline engine-powered leaf blower (GLB) used in landscape maintenance. The GLB is considered to be particularly noxious, affecting citizens with protracted loud noise and toxic, carcinogenic emissions, and ground-based pollutants. Many municipalities have enacted ordinances to restrict their use. This paper describes features of the GLB that have made it the target of citizen protests, presents the results of a recent pilot study conducted to characterize the emitted sound, and recommends steps to address the public health problem presented by the growing use of GLBs.

1 INTRODUCTION

Two-stroke engines used in landscape maintenance activities are an under-recognized source of localized air pollution and disruptive noise used increasingly in American and other communities around the world. As of 2011, more than 121 million pieces of gasoline-powered lawn and garden equipment **(**GLGE**)** were in operation in the US, approximately one-third of which are handheld and powered primarily with two-stroke engines used commonly in landscape maintenance (**Figure 1**) (1). These machines are being used today to perform nearly all tasks once performed manually.



GLGE: Gasoline-powered lawn and garden equipment

The commercial landscape maintenance industry has grown dramatically over recent decades and currently accounts for over 1 million documented workers in the US (2). It is a currently a $77 billion industry (3). Despite the size and impact of this industry, the problem of their pollution and noise is typically considered to be a local one. The National Academy of Engineering report, *Technology for a Quieter America* (4) neglected to address this problem and there has been a failure of local governments to effectively address it as well. In the case of GLBs, this includes not only leaf removal from turf, but also cleanup of debris from road shoulders, driveways, walkways, and roof gutters.

Among this handheld equipment, the gas-powered leaf blower (GLB) is considered to be particularly noxious, affecting citizens with protracted loud noise and toxic, carcinogenic emissions and ground-based pollutants (5). More than 11 million GLBs were estimated to be in use in the US in 2011 and it is possible this number is considerably higher (1). Many towns and cities in California and other parts of the country have enacted ordinances to restrict their use (6) and many others are trying.

GLB emissions and their health effects have been extensively studied. However, studies of GLB sound are scarce. Accordingly, two scientists from Quiet Communities (www.quietcommunities.org) designed a pilot study to characterize the sound and its ability to travel over distance. This paper describes some of the features of the GLB that have made it the target of citizen protests and presents the results of the recent pilot study.

2 BACKGROUND

Most GLBs are powered with inefficient two-stroke engines, designed to minimize weight and maximize power. They emit large volumes of toxic and carcinogenic air pollution and generate loud noise. Manufacturers and industry associations have issued guidelines and recommendations for proper use (7, 8) but they are rarely observed. For example, contrary to industry recommendations, it is common to see: multiple GLBs in use simultaneously; GLBs used to remove dust and debris; GLBs operating at full throttle in residential and other noise-sensitive areas; GLBs used within 50 feet of people; and, workers operating GLBs without hearing and respiratory protection.

Increasingly, commercial grade GLBs are regularly used in and around residential neighborhoods, schools, parks, and other public spaces. Workers using them are exposed at close range to GLB noise and emissions several hours a day, several days a week, throughout seasons of use. Other members of the public, including children, are exposed to high levels of emissions and noise. These factors are raising concerns about hearing and broader health impacts of GLB on workers and the public.

3 GLB EMISSIONS AND HEALTH

GLGE, such as GLBs, emit volatile organic compounds (VOC), including benzene,1,3-butadiene, and formaldehyde; carbon monoxide, nitrogen oxides (NOx), fine particulate matter less than 2.5 micron in diameter (PM2.5), as well as the greenhouse gas, carbon dioxide. Together the VOCs and NOx produce ground level ozone in the presence of sunlight. PM2.5 has been declared a human carcinogen by the cancer research arm of the World Health Organization (9). Quiet Communities has analyzed these emissions nationally and in selected states (1). For

instance, **Table 1** shows levels of pollutants emitted by GLGE and other types of lawn and garden equipment in Massachusetts.

Table 1. Exhaust Emissions from Gasoline-Powered Lawn and Garden Equipment,* Massachusetts, 2011

Pollutant	**Tons Per Year**
Carbon dioxide	497,790
Volatile organic compounds	9,984
Nitrogen oxide	1,740
Carbon monoxide	132,043
Fine particulate matter (< 2.5 micron diameter)	449

Source: Quiet Communities, Inc.
*Includes mowers, leaf blowers/vacuums; edgers/trimmers/cutters; tractors; chain saws; snowblowers; and other.
Information can be obtained on a state-by-state basis on request.

Adverse health effects from these emissions are well known. Benzene, 1,3 butadiene, and formaldehyde comprise three of the four top ranking carcinogens (10), which are known to cause lymphoma, leukemia, and other types of cancer (11, 12). Ground level ozone (formed by VOCs and NOx in the presence of sunlight) and fine PM are known to cause or contribute to early death, heart attack, stroke, congestive heart failure, asthma, chronic obstructive pulmonary disease, and cancer (9, 13-18). Growing evidence suggests these pollutants also contribute to developmental and neurological disorders, including autism (15-20). The mounting evidence on the dangers of short term exposure are especially concerning (15-18).

The high levels of VOCs and fine PM from GLGE pose serious health risks for workers and members of the public close to the emitting source. Although no studies of grounds maintenance workers were found, studies of gas station workers have shown that regular exposure to gasoline vapors can produce hematological and immunological abnormalities and elevate the risk of cancer (21-23). In addition, children, seniors, and persons with chronic illnesses are especially vulnerable to the negative health impacts of GLGE emissions (14). Routine use of GLGE in the vicinity of residential neighborhoods, schools, parks, and other public spaces may be exposing the public to unnecessary and preventable health risks.

4 GLB NOISE AND HEALTH

Complaints about noise from GLBs involve the loudness, duration, impact of constant throttling up and down of the engine, sound quality (which has been said to have a tonal component), long distances over which the sound can be heard, and the ability of the sound to penetrate building walls (24). GLBs are designed for power, not weight. They are housed in lightweight metal that offers little sound isolation. They run at around three times the speed of an automobile engine and produce a loud, monotonous, and piercing sound (25). In industry parlance, it has been referred to as "the scream." Many people have described the sound of the GLB as intolerable.

According to manufacturer specifications and industry training materials, sound pressures from commercial GLBs range from around 95 to 110 A-weighted decibels (dB[A]) at point of operation and from 65−80 dB(A) at 50 feet (26). These levels exceed NIOSH and OSHA thresholds (85−90 dB) for hearing protection (27, 28) as well as community outdoor standards of the World Health Organization (WHO) and US Environmental Protection Agency (55 dB) (29, 30). Apart from industry reported dB(A) measurements, GLB sound and its ability to travel over distance has not been well characterized.

4.1 The Pilot Study

As part of an effort to help communities understand and responsibly regulate GLGE, a pilot investigation was carried out to extend the understanding of GLB sound and its potential impact in a community setting. The host community, Lincoln, MA, has national symbolic importance because it is home to Henry David Thoreau's Walden Pond, widely regarded as the birthplace of the environmental conservation movement in America. The town was also the home of two important acoustical pioneers, Richard Bolt and Robert Newman who founded the company, Bolt, Beranek and Newman.

The study involved the operation of two commercial leaf blowers (62−72 cubic centimeters) and a hose vacuum; this combination of machines is commonly used in commercial landscape maintenance. The sound was measured at point of origin and at three points at five regularly spaced intervals up to 800 feet. Sound pressure was measured with an Optimus Red Octave Band Analyzer CR-162C. All measurements were recorded on the same day under the same environmental conditions.

The main results of the study were: 1) dB(A) levels exceeded community outdoor daytime sound standards at distances up to 800 feet from the origin; 2) high frequency sound was present at point of origin but diminished rapidly; 3) loud low frequency sound dominated at all distances. Loud low frequency sound from GLBs helps explain the distress people experience from chronic exposure to GLB sound. Low frequency sound travels over long distances and can penetrate building walls. Staying indoors does not necessarily confer protection. Rather, it is likely that operating GLBs results in excessive noise in buildings, such as schools, hospitals, and retirement facilities, that exceed safe indoor noise standards.

The loud noise at point of origin is concerning for workers who use GLBs on a regular basis, especially in the absence of hearing protection. Hearing protection training materials specific to lawn and garden equipment indicate that a 25-year-old exposed to more than 85 dB for 8 hours a day for 10 years has a 2 in 3 chance of hearing damage (26). Adverse health effects from exposure to low frequency sound are concerning not only for workers, but other members of the public. The known effects are largely non-auditory and include annoyance, stress, stress-induced cardiovascular responses, and sleep disturbance (29, 32, 33). Continuous stimulation of these stress-related responses is known to result in hypertension, ischemic heart disease, heart attack, and stroke (34). Particularly at risk are the more vulnerable populations that include children, seniors, and people with chronic illnesses.

The strong low frequency component of GLB sound suggests that dB(A)-based metrics (which underweight low frequency components) are not sufficient descriptors of this sound and do not convey enough information regarding potential impact on communities (29, 32, 33, 34). Metrics that account fully for low frequency components are needed for citizens and policy makers to

better understand the impact that GLBs have on communities. The use of psychoacoustic metrics should also be considered to better understand the subjective human response to GLB sound (35).

5 IMPLICATIONS

The permitted use of machines that produce high levels of toxic and carcinogenic compounds and that also emit harmful sound capable of traveling long distances is a public health issue that needs to be fully addressed by scientists, health professionals, and local, state, and national government agencies. The harmful effects of GLB sound are not fully appreciated by the public and by decision makers. A first step towards addressing this issue is to require published equipment specifications to include metrics that adequately represent GLB sound and its potential impact on the community; revised metrics would account properly for the strong low frequency component and tonal components of emitted sound. A second step is to educate health professionals and policy makers on the impact this type of sound may have on surrounding communities.

6 CONCLUSIONS

GLBs have become an important, but under-recognized, source of toxic and carcinogenic exhaust, ground-based particulates, and harmful noise in many communities in the U.S. and around the world. As a source of dangerous air pollutants and noise, the burgeoning use of this equipment can result in serious harm to the health of workers, children, seniors, and other members of the public. While the impacts of noise on health are widely recognized, those from the two-stroke engine are not. It is essential to recognize that this form of community noise is a broad public health problem, and not one that engineers should attempt to handle alone.

Acoustic pioneers, Bolt and Newman, recognized the value of quiet communities and the need to effectively address the public health problem of noise through their work with research teams composed of public health/medical professionals, policy makers, engineers, and responsible citizen advocacy groups rooted in science. Now, forty years later following their pioneering work, it is also imperative to recognize the latest thinking on metrics which in this case means using a broader set of metrics that adequately represent the character of the sound as well as measures that reflect the psycho-physical responses of humans and other living things.

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