

**Different hazards to examine (and questions this report seeks to address):**

- I. **Noise** - *How does noise affect workers, children, adults and seniors? What are the WHO standards for noise?*
- II. **Dust, biohazards, particulate matter** – *how do fumes, oil contaminants, aerosols, dust affect workers and community members (children, adults, senior adults, asthma sufferers)?*
- III. **Environmental health** – *Do two-stroke engines contribute to greenhouse gas emissions? Do two-stroke engines destroy insect habitats? How do two-stroke engines affect topsoil? Does noise from two-stroke engines destroy the natural biophony?*
- IV. **Alternatives to two-stroke engine lawn equipment** – *Is there an appetite and a market for battery-powered systems? Are there less noisy, less polluting models?*

**I. Noise**

*How does noise from two-stroke leaf blower affect workers?*

Noise specifications are typically measured from about 50-feet away from blower.<sup>1</sup> Therefore, operators and nearby workers experience significantly higher noises. Many newer leaf models set the specification that noise should not exceed 65 dB from 50 feet away. But even with this recommendation, operators may experience levels even greater than 85 dB, which can result in hearing loss.<sup>2,3</sup> Notably, OSHA requires employers to implement a noise exposure program to employees exposed to average noise levels of 85 dB over 8 hours of work.<sup>4</sup> Under these standards, the casual user (or even an operator at a landscaping “mom and pop” boutique) is unlikely to break compliance but still may experience hearing loss resulting from noise exposure.<sup>2-3</sup>

To the best of our knowledge, no detailed quantitative study shows how long an average user is exposed to these noises, but for the purposes of this report we can safely assume that this value is greater than zero, and any exposure to loud noises above 85 dB can result in hearing damage or loss.<sup>2,3</sup>

*How does noise from two-stroke leaf blowers affect community members?*

Children are at high risk for hearing damage as they are developing.<sup>5,6</sup> Leaf blowers operating above an effective decibel volume (i.e., the volume perceived) of 45 dB are likely to disrupt the sleep of infants, toddlers, second and third shift workers. Leaf blowers are often used much closer than 50 ft (for example, when used near an external wall), meaning that the effective volume is often much greater than 45 dB and likely to be audible indoors.<sup>7-9</sup>

While many different types of lawn equipment (e.g., lawn mowers, weed eaters, leaf blowers) make noise, those with tonal components like leaf blowers tend to elicit the strongest annoyance.<sup>7</sup> Low-frequency sound waves travel further than shorter waves and are also less likely to be abated by walls or nearby objects like trees.<sup>7</sup> Without proper abatement, low-frequency noise can be as loud as 65 dB from 800 ft away.<sup>8</sup>

Perceived Sound Level	Sound Level		Examples	Leaf Blower Reference
	dB	$\mu\text{Pa}$		
<b>PAINFULLY LOUD</b>	160	$2 \times 10^9$	fireworks at 3 feet	
	150		jet at takeoff	
	140	$2 \times 10^8$	threshold of pain	OSHA limit for impulse noise
<b>UNCOMFORTABLY LOUD</b>	130		power drill	
	120	$2 \times 10^7$	thunder	
	110		auto horn at 1 meter	90-105 dB leaf blower at operators ear
	100	$2 \times 10^6$	snowmobile	90 dB OSHA permissible exposure limit
<b>VERY LOUD</b>	90		diesel truck, food blender	
	80	$2 \times 10^5$	garbage disposal	
	70		vacuum cleaner	62-75 dB Leaf blower at 50 feet
<b>MODERATELY LOUD</b>	60	$2 \times 10^4$	ordinary conversation	
	50		average home	
<b>QUIET</b>	40	$2 \times 10^3$	library	
	30		quiet conversation	
<b>VERY QUIET</b>	20	$2 \times 10^2$	soft whisper	
	10		rustling leaves	
<b>BARELY AUDIBLE</b>	0	$2 \times 10^1$	threshold of hearing	

dB= decibels  
 $\mu\text{Pa}$ = micro Pascals

Figure 1: Reproduced from California EPA study (2000)<sup>10</sup>

## II. Dust, particulate matter, fumes, biohazards

*How do fumes, oil contaminants, aerosols, dust affect workers? Community members?*

### A. Emissions

Two-stroke engines are an obvious source of emissions, including burned and unburned fuel, carbon monoxide (CO), nitrous oxide (NO), benzene, 1,3-butadiene, acetaldehyde and formaldehyde.<sup>10</sup> By the very nature of these engines, fuels are mixed with lubricating oils. A single two-stroke engine produces the equivalent pollution of 30-50 four-stroke engines. A 1999 study provided a further benchmark: Hydrocarbon emissions from 30 minutes of blower operation (from a two-stroke engine) equal about 8000 miles of driving at an average speed of 30 miles per hour.<sup>10</sup> A 2017 study cited in the Wall Street Journal accounts for the improvement engine efficiency: Operating a two-stroke engine for 1-hour is equivalent to driving a 2016 Toyota Camry about 1200 miles.<sup>11</sup> Two-stroke engines also release more nitrogen oxides (NO<sub>x</sub>) and carbon monoxide (CO) than high-performance pick-up trucks.<sup>12</sup> A 2008 study cites that outdoor air pollution kills more than 800,000 people globally per year and sickens many more.<sup>13</sup>

### B. Fugitive dust

Fugitive dust is dust resuspended in air through the act of blowing, raking, etc. It is difficult to quantify the degree of fugitive dust attributed solely to two-stroke engine lawn equipment, though certainly tools that blow hurricane force winds greater than 185 mph can generate a significant amount of dust that can irritate passersby.<sup>10,14</sup> To mitigate this problem, gardeners could switch off the blowing function when someone passes by and

avoid blowing debris into the street where they will get kicked up by passing automobiles.

### C. Fecal matter

The Orange County Grand jury (1999) and the City of Palo Alto (2000) found that animal droppings were spread by leaf blowers.<sup>10</sup> Animal droppings make humans sick. *Campylobacter jejuni*,<sup>15</sup> *Cryptosporidium* spp.<sup>16</sup> and *Toxoplasma oocyst* (parasite from cat feces)<sup>17</sup> are just some of the diseases that can be spread through leaf blowers. Notably, however, other lawn equipment – including rakes and lawnmowers—can also potentially spread fecal matter. Notably, epidemiologists believe that these infections are most commonly transmitted through drinking untreated water contaminated with infected animal droppings.<sup>15-17</sup> These risks can be mitigated by enforcing that pet owners clean up after their pets and limiting community exposure to sick pets. Lastly, community members can also protect themselves by washing their hands before touching their face or eating and not drinking untreated water.<sup>15-17</sup>

## III. How do two-stroke engines impact environmental health beyond emissions?

- A. Leaf blowing can degrade the soil as fallen leaves and yard debris could form natural mulch. Also, leaf blowing removes moisture from the base of trees, which can increase watering needs.<sup>18</sup>
- B. Fallen leaves, vegetation and debris form the natural habitat for many insects including some bee species. Lower insect populations could prove detrimental to birds, etc. therefore, leaf removal (including through blowing) could have a devastating impact on the ecosystem.<sup>18</sup>
- C. (Carbureted) two-stroke engines banned in certain California water ways (due to emission pollution);<sup>19</sup> these types of engines were largely supplanted circa 2000 with direct inject engines. A 2001 study found Elk had increased stress hormone in their urine due to snowmobile usage in their habitat.<sup>20</sup> To the best of our knowledge, no report exists on how leaf blowers specifically cause disease in humans, though notably there are multiple complaints about the noise from leaf blowers disrupting sleep patterns (especially of small children and people working second or third shift), which can have a profound impact on health.<sup>10</sup> Importantly, these studies are not firmly controlled and health outcomes cannot be solely attributed to two-stroke engines.

## IV. Alternatives to the two-stroke engine

Most technologies are focused on becoming “cleaner” – the two-stroke engine bucks this trend.

- A. Battery-powered alternatives are cleaner, but tend to have less power.<sup>21</sup>
- B. A famous example of a lady in her 50s clearing her yard in shorter time than electric leaf blower and almost as fast as gas-powered leaf blower.<sup>22</sup>
- C. Zero-scaping where there is no need to move leaves and debris
- D. Perform some education around not needing most powerful blowers for all jobs (e.g., powerful blowers are required for jobs with heavy leaf cover, but battery-powered or electric equipment may be preferable for edge work like sweeping grass from sidewalks).

**Annotated References** (summarizes methodology and key scientific findings when applicable):

- 1 P. Hope. Quietest **Leaf Blowers and Outdoor Power Gear** *Consumer Reports* 12 October 2019 <https://www.consumerreports.org/tools-power-equipment/quietest-leaf-blowers-and-outdoor-power-gear/> (Accessed October 2019)  
Consumer Report rankings of leaf blowers and other outdoor equipment based on various specifications like noise levels and power
- 2 Centers for Disease Control and Prevention. **What noises can cause hearing loss?** [https://www.cdc.gov/nceh/hearing\\_loss/what\\_noises\\_cause\\_hearing\\_loss.html](https://www.cdc.gov/nceh/hearing_loss/what_noises_cause_hearing_loss.html) (Accessed October 2019)  
CDC reference sheet on hearing loss
- 3 National Institute on Deafness and Other Communication Disorders <https://www.nidcd.nih.gov/health/noise-induced-hearing-loss> (accessed 9 November 2019)
  - Hearing loss reference sheet
  - Metric and benchmark for different noises
- 4 United States Department of Labor. Occupational Noise Exposure <https://www.osha.gov/SLTC/noisehearingconservation/> (Accessed 2 January 2020)  
Reference sheet for regulations and standards around occupational noise exposure
- 5 D. Millis. **Leaf blowers are not healthy for children and other living things** *Monrovia Neighbor News* <https://patch.com/california/monrovia/leaf-blowers-are-not-healthy-for-children-and-other-living-things> (Accessed December 2019)  
Example complaint (opinion piece) on the basis of noise, emissions and other environmental concerns
- 6 P. Landrigan *et al.* **Medical grounds for a restriction on Internal Combustion Power Tools and Leaf Blowers** [http://www.lincolntown.org/DocumentCenter/View/733/PEHSU\\_Eastchester\\_letter\\_042210\\_1\\_?bidId=](http://www.lincolntown.org/DocumentCenter/View/733/PEHSU_Eastchester_letter_042210_1_?bidId=) (Accessed December 2020)
  - On April 22, 2010, every doctor in the pediatric environmental health specialty unit at Mt. Sinai Hospital signed a letter supporting a four-month ban- for two-stroke engine lawn equipment on the basis of potential hearing damage.
  - Made special note that children breathe more air per pound of body weight per day, which makes them vulnerable to emissions and fugitive dust kicked up by these machines
- 7 K. Perrson and M. Bjorkman. **Annoyance due to low frequency noise and the use of the dB(A) scale** *Journal of Sound and Vibration* 1988 Volume 127(3).
  - 98 subjects exposed to 4 x 30 minutes – two out of 80, 250, 500 and 1000 Hz. Given questionnaire. Low frequency considered more annoying than high frequency.
  - dB(A) – underestimates noise by 3 dB for levels around 65 dB (lin); underestimates noise by 6 dB for levels around 70 dB (lin)
  - Low frequencies are less attenuated by air and ground
  - No Statistically significant relation between age and degree of annoyance
  - Annoyance level graphs (Figure 5) – show equal annoyance, Same increase in noise level (as measured by decibels) elicits more annoyance at lower frequencies

- Annoyance at low-frequency noise is higher in areas with a low background level, e.g., during hours of the day when ambient noise is lower.
- 8 E. Walker and J.L. Banks **Characteristics of lawn and garden equipment sound: A community pilot study** *Journal of Environmental Toxicological Studies* 2017 Dec; 1(1)
- WHO standards – 55 dB(A)
  - Measured low-, medium-, high-frequency components of sounds from two backpack leaf blowers and a hose vacuum.
  - Concentric circles 50 ft, 100 ft, 200 ft, 400 ft and 800 ft from centroid
  - Takeaway: low-frequency components travel further and attenuate less
- 9 T. Pasanen et al. **Leaf Blower Noise** *Joint Baltic-Nordic Acoustics Meeting 2004*, 8-10 June Mariehamn Åland <http://www.akustinenseura.fi/wp-content/uploads/2013/08/o46.pdf>
- Measured leaf blower noise of popular leaf blowers and other professional lawn equipment with 6 microphone positions arranged in a semicircle
  - Tabulates noise emissions, user exposure and emission spectrum figure references for each machine tested
  - Loudest noises were observed for two-stroke engine leaf blower with the most power
- 10 California Environmental Protection Agency, Mobile Source Control Division . **A report to the California Legislature on the potential health and environmental impacts of leaf blowers** February 2002, <https://ww3.arb.ca.gov/research/apr/reports/l828.pdf> (Accessed 4 November 2019)
- Discusses findings from noise pollution
  - Particulate matter/ fugitive dust explanation
  - Exhaust and emissions benchmark
- 11 D. Fitz *et al.* **Determination (sic) particulate emission rates from leaf blowers** *Environmental Protection Agency conference proceedings* <https://www3.epa.gov/ttnchie1/conference/ei15/session5/fitz.pdf>
- Spiked clean surfaces with dirt, measured using filters and light scattering
  - 2m x 2m x 10m (or 20m) chambers
  - compares leaf blowers to raking on cement and asphalt
- 12 J.C. McGinty **That ear-splitting leaf blower? It also emits more pollution than a car** *Wall Street Journal* 15 December 2017 <https://www.wsj.com/articles/that-ear-splitting-leaf-blower-it-also-emits-more-pollution-than-a-car-1513346400>  
Provides more recent benchmark to emissions from two-stroke engine leaf blowers
- 13 **Leaf blower's emissions dirtier than high-performance pick-up truck's (sic), says Edmunds' InsideLine.com** *Edmunds* 6 December 2011 <https://www.edmunds.com/about/press/leaf-blowers-emissions-dirtier-than-high-performance-pick-up-trucks-says-edmunds-insidelinecom.html> (Accessed January 2, 2020)
- Consumer-grade leaf blowers emit more pollutants than 2011 Ford F150 ("F150") pickup truck
  - Echo two-stroke leaf blower generated greater than 20 times the carbon monoxide and 300 times the amount of non-methane hydrocarbons as the F150

- A half-hour of yard work with a two-stroke leaf blower is equivalent to driving the F150 3900 miles
- 14 D. Kushner **Two strokes and you're out** *Discover Magazine* 20 May 2008  
<https://www.discovermagazine.com/environment/two-strokes-and-youre-out> (Accessed October 2019)
- Provides 2008 estimate that air pollution kills more than 800,000 people per year and sickens a far greater number
  - Ortega offered economic incentives (e.g., a \$200 loan for an upgrade to a four-stroke engine) to get rid of two-stroke engine
  - Article speaks to the high cost of upgrading to many poor people
  - Mentions tech start-up that attempts to retrofit two-stroke engines (kits reduce hydrocarbon emissions by 90% and increase fuel efficiency by as much as 35%)
  - Cites EPA role in curbing emissions from two-stroke engines in Asia (particularly in using retrofitting to tackle pollution in India)
- 15 Center for Food Security and Public Health **Zoonic campylobacteriosis**  
<http://www.cfsph.iastate.edu/Factsheets/pdfs/campylobacteriosis.pdf>  
 Campylobacteria fact and resource sheet
- 16 Centers for Disease Control and Prevention  
<https://www.cdc.gov/parasites/crypto/general-info.html> (Accessed October 2019)  
 Cryptosporidium fact and resource sheet
- 17 E. F. Torrey and R. H. Yolken **Toxoplasma oocysts as a public health problem**  
*Trends in Parasitology* 29(8), pp. 380-384
- *Toxoplasma gondii* oocysts are spread from cats
  - typical measurement 3 to 350 oocysts/ square foot
  - can be mitigated by lowering reducing feral cat population, keeping cats indoors, properly disposing cat litter and limiting the area where children play
- 18 *Master Pollinator Program* **Native insect pollinators and their habitats** *University of Missouri Extension*.  
<https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/67463/NativeInsectPollinatorsandTheirHabitats.pdf?sequence=1>
- Bumblebees and other insects prefer habitats with coarse vegetation and natural debris
  - Many insects make nests in vegetation debris and abandoned rodent burrows (which are often found near fallen debris)
  - Bumblebees, in particular, must forage close to their nests, which have little storage capacity
- 19 California Division of Boating and Waterways **Two-stroke vessel engines**  
[https://dbw.parks.ca.gov/?page\\_id=28770](https://dbw.parks.ca.gov/?page_id=28770) (Accessed October 2019)  
 Resource for two-stroke engine use on California waterways (currently no statewide bans, but regulations exist on specifications for new boats with two-stroke engines that haven't been sold to an end-user before)
- 20 B. Krause. **The sound of a damaged habitat** *The New York Times* 28 July 2012  
[https://www.researchgate.net/profile/Bernie\\_Krause/publication/257943543\\_The\\_Sound\\_of\\_a\\_Damaged\\_Habitat/links/00b7d5266932cf3dad000000.pdf](https://www.researchgate.net/profile/Bernie_Krause/publication/257943543_The_Sound_of_a_Damaged_Habitat/links/00b7d5266932cf3dad000000.pdf) (Accessed October 2019)

Cited reference that snowmobile noise raised the levels of stress hormones in their feces and that the levels returned to normal concentrations when the intrusive din was absent

- 21 R. Berendsohn. **The 10 best leaf blowers for any size yard** *Popular Mechanics* <https://www.popularmechanics.com/home/tools/a24539816/best-leaf-blowers/> (Accessed October 2019)
- Tested 10 leaf blowers: traditional gas-powered and battery operated
  - Performed several tests:
    - Erosion test (sawdust on 6 ft x14 ft plot of pavement – point leaf blower at it to see how much sawdust is displaced in a single blow at full speed)
    - Leaf clearing test (layer of leaves on a 6 ft x 12 ft rectangle of grass – see how easily leaves can be cleared at full speed)
    - Run time (measured how long blowers have power when at full throttle)
    - Air speed (used an anemometer that can measure precise speeds up to 250 mph)
- 22 Citizens for a quieter Sacramento **Leaf blowers and health: A letter to California Air Resources Board** <https://www.nonoise.org/quietnet/cqs/new.htm> (Accessed October 2019)
- Participants (a woman with a rake versus a man with a leaf blower) had to undertake 3 tests (shown below)
- Clean a patio with 8 chairs (gas-powered leaf blower <2 minutes, burly man; rake 2:30 second, 50+ year old woman) – rake did a better job at clearing debris like tiny pebbles
  - Paper cups and wadded paper down a 50-foot slope and up again (rake/ woman faster than gas-powered leaf blower/ man) – some indication that leaf blowers spread material
  - Heavy bed of pine needles down and up a 30-foot slope (rake/ woman faster and more accurate than gas-powered leaf blower/ man) – some indication that leaf blower not as accurate and can spread fugitive dust.