APPENDIX A

SENATE CONCURRENT RESOLUTION 19

APPENDIX B

CONTACT LIST

Leaf Blower Report Contact List

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APPENDIX C

AMBIENT AIR QUALITY STANDARDS

APPENDIX D

CHEMICAL SPECIATION PROFILE

FOR PAVED ROAD DUST

APPENDIX E

PHYSICAL PROPERTIES OF SOUND

AND LOUDNESS MEASURES

Physical Properties of Sound

Sound is defined as vibrations in a medium, such as air or water, that stimulate the auditory nerve and produce the sensation of hearing. The vibrations propagate outward from the source of the sound in the form of pressure waves, traveling in straight lines in all directions outward from the source, as with the ripples in a pond resulting when one drops a rock into the water. Sound is a form of mechanical energy and is measured in energy-related units (WHO 1980).

The speed of sound depends on the properties of the medium through which the sound wave moves. Sound travels more rapidly through air than through water, but may travel more rapidly through a solid than through air (Sataloff & Sataloff 1993). Sound waves, however, do not transmit through a vacuum. At sea level and 68^{o} F, the speed of sound through air is 770 miles per hour, or 344 meters per second. A "sonic boom" is heard when an object is traveling through air faster than the speed of sound, which creates an impulse of sound from the leading and trailing edges of the object (Kryter 1994).

Sounds are characterized by pitch, loudness, quality, and duration. Leaving aside duration, each of these is a psychological sensation, largely correlated to the physical attributes of frequency, intensity, and overtone structure, or timbre. Other physical factors, however, also influence the perception of sound. Sounds can be distorted by the wind, rendering them quieter or louder depending on the relative direction of the wind. Sound waves can bend around an obstacle, such as a wall, pass through the object unaffected, be reflected off the object, or be partially reflected and partially passed through or around the object. Two sound waves can also have the effect of canceling or amplifying each other at fixed distances from the source. Each of these behaviors depends on physical characteristics of the sound waves; frequency, amplitude, and wavelength; and physical characteristics of the environment (Sataloff & Sataloff 1993).

The sensation of pitch is related to the number of vibrations per second of a sound wave, which is called the sound's frequency, and is measured in Hertz (Hz). A whistle and bird song, for example, are high frequency sound, and thunder and the bass line of a rock song are low frequency sound. The normal hearing range of a young, healthy person ranges from about 20 Hz to 20,000 Hz (20 kHz). Some animals can hear lower and higher frequencies than can humans; for example bats, moths, and dogs hear frequencies higher than the human hearing range. Loss of hearing acuity involves the inability to hear sounds of certain frequencies, usually at the upper and lower bounds of normal hearing.

A sound that is made up of only one frequency is a pure tone. Most sound is made up of more than one tone, or several frequencies, sounding together. The quality, or timbre, of a sound is related to the presence and intensity of the additional tones contained in the sound; these overtones are the result of different frequencies sounding at the same time, resulting in a complex waveform. In addition, sound timbre includes the pattern of change over time of each of the tones. The relative intensity and pattern of change of each frequency in the sound is what allows us to describe sounds of the same fundamental frequency as tinny, flute-like, or brassy. One can thus discriminate between the human voice, a flute, a violin, and a french horn, each playing the same note. Industrial noises, on the other hand, consist of a wide mixture of frequencies, known as broad band noise. A sound composed of frequencies that are evenly distributed throughout the audible range is termed white noise and sounds somewhat like rushing water (Brüel & Kjær 1984).

Sound duration can be described by the pattern of sound in time and intensity, or level, and can be described as continuous, fluctuating, impulsive, or intermittent (U.S. EPA 1979). Continuous sounds are those produced for a long period of time at a relatively constant level, such as the rushing of water in a river. Fluctuating sounds vary in level over time, such as traffic noise at an intersection. Impulse noises are those sounds with an extremely short sound pressure peak of less than a second in total duration. Impulse noises may be repetitive and occur close together, as in hammering or riveting; be spaced out in time, as in manual hammering; or occur as a single event, such as a single gun shot or explosion (Niedzielski 1991). Intermittent noises are those recurring noises lasting a relatively short period of time, such as the ringing of a phone, or aircraft take offs and landings.

The intensity, or magnitude, of sound is described by the size or amplitude of the fluctuation in sound pressure. In general, the larger the amplitude, the louder the sound, although other factors also affect the perceived loudness of a sound. Over moderate distance, sound intensity decreases at a rate inversely proportional to the square of the distance from the source (Sataloff & Sataloff 1993). Thus, halving the distance from the source of the sound quadruples the sound intensity, assuming there are no interfering surfaces to reflect the sound waves.

Measures of sound loudness

Different measures of sound loudness have been developed for the general purpose of relating, with respect to effects on people, the amount of sound energy exposures (Table 1). For a single event exposure, the descriptor is SEL or L_{ex}. For a composite measure of the sound level of a number of events over a specified time, the descriptor is L_{eq}, measured over 8-hours for occupational exposures, or 24-hours, for characterizing lifetime occupational and non-occupational exposures. A composite measure of average sound levels in residential areas throughout the day and night adds a 10-dB penalty for noise that occurs from 10:00 p.m. to 7:00 a.m (DNL or L_{dn}) (EPA 1974). Finally, California has developed a variant of the DNL that applies to aircraft and airport noise, the Community Noise Equivalent Level (CNEL) (21 CCR §5001). The CNEL adds a 3-dB penalty for noise occurring in the evening, from 7:00 p.m. to 10:00 p.m., and a 10-dB penalty for noise occurring at night, from 10:00 p.m. to 7:00 am.

Table 1. Sound Descriptors (dBA)[1]

Name of Descriptor	Notation	Nature of Descriptor	Typical Use
Sound Exposure Level, or Single Event Noise Exposure Level	SEL, SENEL, or L_{ex}	A summation of the energy of the momentary magnitudes of sounds associated with a single event to measure the total sound energy of the event.	To describe noise from a continuous noise occurring over time
Equivalent Sound Level	L_{eq}(8) or (24)	The sound level that is equivalent to an actual time varying sound level, in the sense that it has the same total energy for the duration of the sound.	To measure average environmental noise levels people are exposed to on the job (8-hrs) or all day (24-hr) for use in determining lifetime exposures
Day-Night Sound Level	DNL or L_{dn}	The equivalent sound level for a 24-hr period with 10 dB penalty for nighttime sounds from 10:00 p.m. to 7:00 am	To characterize average sound levels as perceived in residential areas throughout the day and night
Community Noise Equivalent Level	CNEL	The equivalent sound level for a 24-hr period with 3-dB penalty for evening sounds, from 7:00 p.m. to 10:00 p.m., and 10-dB penalty for nighttime sounds, from 10:00 p.m. to 7:00 am	To characterize average sound levels as perceived in residential areas impacted by aircraft/airport noise

1From EPA 1974, EPA 1979, Kryter 1994, and 21 CCR §5001.

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APPENDIX F

AMERICAN NATIONAL STANDARD

FOR POWER TOOLS –

HAND-HELD AND BACKPACK,

GASOLINE-ENGINE-POWERED BLOWERS

B175.2-1996

ANSI®

APPENDIX G

MANUFACTURER-REPORTED NOISE LEVELS

FROM LEAF BLOWERS

Manufacturer-Reported Noise Levels from Leaf Blowers

The data on leaf blowers in the following table were collected from manufacturer-provided brochures and from Internet web sites. Web sites were checked, when possible, to verify the information in brochures, especially when brochures were older than 1999. No attempt was made to determine which of the leaf blowers are available for sale in California. In addition to noise levels, reported for each model are also the type of blower, whether hand held, backpack, or wheeled (walk-behind); the engine displacement (cc), reported air volume; and air speed. Some manufacturers noted whether they reported maximum air volume and air speed or the average air volume and air speed, but these were not distinguished in the table. Air volume was sometimes reported as without tubes, or the air volume exiting the housing, and with tubes, or the air volume exiting the unit with the blower tubes in place. The notes column includes miscellaneous information, such as whether the unit includes a vacuum option, and model names.

Ninety-one blowers are listed in the table, 55 of which have reported sound pressure levels. Electric-powered blowers make up 21% of the total. Approximately half of all models are hand held, 41% of which are electric models. Backpack models are 42% and wheeled models are 8% of the total; there are no electric-powered backpack or wheeled leaf blowers. Of the 55 models that have manufacturer-reported noise levels, more than half (55%) reported noise levels to be 69 to 70 dBA. A slightly higher proportion of the blowers were quieter than 69 dBA (27%) than were louder than 70 dBA (18%). Manufacturers usually noted that noise levels were reported at 50 ft, implying the use of ANSI test method; even if not stated, all reported noise levels were assumed to have been recorded at 50 ft. The quietest gasoline-powered blowers, all backpack models, are the Maruyama BL4500 (62 dBA), Toro BP6900 (62 dBA), and Echo PB46LN (65 dBA). The quietest electric-powered blowers, all hand held models, are the Toro 51589 (63 dBA), the Stihl BGE60 (63 dBA), and the cordless Poulan/Weedeater VROOM (63 dBA).

Brand	Model	Type	Noise Level (dBA)	Engine Displacement (cc)	Engine Power	Air Volume (cfm)	Air Speed (mph)	notes
Billy Goat	QB883	Wheeled	*	N/R	8 hp	N/R	N/R	96 LpA (operator's ear), 89 LwA (ave of 12 readings at 4 m)
Billy Goat	QB1103	Wheeled	*	N/R	11 hp	N/R	N/R	100 LpA, 92 LwA
Billy Goat	QB553HC	Wheeled	N/R	N/R	5 hp	N/R	150	"low noise"
Black And Decker	BV1000	Hand Held	N/R	Electric	12 amp	480	195	"Vac 'N' Mulch"
Black And Decker	BV2000	Hand Held	N/R	Electric	12 amp	480	195	"Vac 'N' Mulch"
Black And Decker	BV3000	Hand Held	N/R	Electric	12 amp	480	195	"Vac 'N' Mulch"
Cifarelli	M88BL	Backpack	N/R	77	5 hp	706	280	Standard model; Italian Co.
Cifarelli	M88BL1	Backpack	N/R	77	5 hp	706	280	With gas lever & stop on frame; Italian Co.
Echo	PB-400E	Backpack	74	39.7	N/R	388 (590)	180	Air volume reported with tubes (without tubes)
Echo	PB-46HT	Backpack	70	44	N/R	370 (740)	180	Air volume reported with tubes (without tubes)
Echo	PB-46LN	Backpack	65	44	N/R	370 (740)	180	Air volume reported with tubes (without tubes)
Echo	PB-60HT	Backpack	71	58.2	N/R	405 (840)	195	Air volume reported with tubes (without tubes)
Echo	PB-2100	Hand Held	69	21.2	N/R	302 (330)	135	Air volume reported with tubes (without tubes)
Echo	PB-210E	Hand Held	69	21.2	N/R	310 (310)	150	Air volume reported with tubes (without tubes)
Echo	PB-24LN	Hand Held	67	23.6	N/R	300 (375)	150	Air volume reported with tubes (without tubes)
Fradan Power Equip.	BB-50	Backpack	67	42	N/R	590	236	
Fradan Power Equip.	see notes	Wheeled	70	N/R	N/R	N/R	N/R	Five models w/ 5hp, 8hp, 9hp, 11hp, &14 hp engines
Homelite	The Backpacker	Backpack	70	30	N/R	425	170	
Homelite	d25b	Hand Held	69	25	N/R	350	150	
Homelite	d30mhv	Hand Held	70	30	N/R	360	160	Vaccum included
Homelite	d30mha	Hand Held	70	30	N/R	360	160	Vacuum kit capable
Homelite	VacAttack	Hand Held	70	25	N/R	360	160	Blower/Vacuum/ Mulcher
Homelite	Yard Broom	Hand Held	69	25	N/R	350	150	
Homelite	Yardvark	Wheeled	69	25	N/R	385	165	
Husqvarna	145BT/BF	Backpack	N/R	40	N/R	340 (589)	175	Air volume reported with tubes (without tubes)
Husqvarna	132HBV	Hand Held	N/R	32	N/R	360	170	Vacuum included
Husqvarna	225HBV	Hand Held	N/R	25.4	1.2 hp	392	128	Vacuum/mulcher attachment optional
John Deere	BH30	Hand Held	69	30	N/R	450	180	Vacuum kit optional
John Deere	BP40	Backpack	69	40.2	N/R	404 (590)	180	Air volume reported with tubes (without tubes)
John Deere	BP50	Backpack	69.5	48.6	N/R	470 (672)	185	Tube-mounted controls; Air vol. with tubes (without tubes)

Brand	Model	Type	Noise Level (dBA)	Engine Displacement (cc)	Engine Power	Air Volume (cfm)	Air Speed (mph)	notes
Jonsered	BV 32	Hand Held	N/R	31.7	0.9 hp	N/R	170	Vacuum included
KAAZ	BA402K	Backpack	N/R	40.2	N/R	586	250	
Kawasaki	KRB400A	Backpack	68	48.6	3.2 hp	380	180	
Makita	RBL250	Hand Held	65.6	24.5	N/R	321	165	Vacuum attachment optional
Makita	RBL500	Backpack	70	48.6	N/R	447	187	
Mantis	BSV	Hand Held	N/R	N/R	N/R	350	130	Blower/Shredder/Vacuum
Maruyama	BLL2600	Hand Held	66	25.6	1.5 hp	300	150	Vacuum attachment optional
Maruyama	BL4500	Backpack	62	40.2	3.2 hp	470	170	
Maruyama	BL5400	Backpack	69	48.6	3.7 hp	520	180	
MTD	652 B	Wheeled	N/R	N/R	5 hp	N/R	200	
Poulan/Weedeater	2510	Hand Held	66	Electric	7.5 amp	280	110	"GroundSweeper"
Poulan/Weedeater	2540	Hand Held	67	Electric	8.5 amp	320	125	"GroundsKeeper"
Poulan/Weedeater	2560	Hand Held	N/R	Electric	8.5 amp	320	125	"GroundsKeeper Plus"
Poulan/Weedeater	2570	Hand Held	71	Electric	12 amp	405	195	"Barracuda Super Blower"
Poulan/Weedeater	2595	Hand Held	71	Electric	12 amp	405	195	"Barracuda Super Blower/Mulching Vac"
Poulan/Weedeater	VROOM	Hand Held	63	Electric	N/R	95	105	"Cordless Broom"
Poulan/Weedeater	GBI 20	Hand Held	N/R	22	N/R	330	140	
Poulan/Weedeater	SV 22	Hand Held	N/R	22	N/R	360	165	"Barracuda Blower/Vac"
Poulan/Weedeater	SV 30	Hand Held	70	30	N/R	375	180	"Barracuda Blower/Vac"
Poulan/Weedeater	BV 1650	Hand Held	70	22	N/R	370	165	"Blower/Vac"
Poulan/Weedeater	BV1800	Hand Held	70	24	N/R	380	180	"Barracuda Super Blower/Vac"
RedMax	EB4300	Backpack	72	41.5	N/R	565	160	"EPA certified"
RedMax	EB431	Backpack	69	41.5	N/R	565	186	"EPA certified"
RedMax	EB441	Backpack	69	41.5	N/R	565	186	"EPA certified"
RedMax	EB6200	Backpack	75	62	N/R	730	200	"EPA certified"
RedMax	EBA431	Backpack	69	41.5	N/R	565	186	"EPA certified"
RedMax	HB2300	Hand Held	68	22.5	N/R	353	150	"EPA certified"
Robin	FL500	Backpack	70	48.6	2 hp	530	260	
Robin	FL 251	Hand Held	N/R	24.5	1.2 hp	272	117	
RYOBI	160r	Hand Held	N/R	electric	9 amp	N/R	120	
RYOBI	180r	Hand Held	N/R	electric	9.5 amp	N/R	130	blower/vacuum/mulcher
RYOBI	190r	Hand Held	N/R	electric	12 amp	N/R	180	blower/vacuum/mulcher
RYOBI	280r	Hand Held	N/R	31 cc.	N/R	N/R	150	
RYOBI	310BVr	Hand Held	N/R	31 cc.	N/R	N/R	150	blower/ vacuum/mulcher
RYOBI	RESV1300	Hand Held	N/R	electric	N/R	350	157	Electric Mulchinator Vacuum

Brand	Model	Type	Noise Level (dBA)	Engine Displacement (cc)	Engine Power	Air Volume (cfm)	Air Speed (mph)	notes
Shindaiwa	EB240	Hand Held	67	24	1.2 hp	307	166	
Shindaiwa	EB480	Backpack	69	43.6	3 hp	415	188	
Shindaiwa	EB500	Backpack	72	43.6	2.3 hp	434	190	
Shindaiwa	EB630	Backpack	75	62	3.9 hp	631	201	
Solo	414	Backpack	N/R	54	3.4 hp	647	N/R	
Solo	470	Backpack	N/R	52.6	3.4 hp	706	N/R	"reduced noise emission by approx. 13 dB(A)" from the 414 model
Stihl	BGE 60	Hand Held	63	electric	1150 W	362	139	
Stihl	BG 75	Hand Held	69	25.4	N/R	377	135	Blower/Vacuum
Stihl	BR 320	Backpack	N/R	44.9	2.7 hp	435 (589)	164	Blower/Vacuum; Air vol. reported with tubes (without tubes)
Stihl	BR 320 L	Backpack	69	44.9	1.9 hp	382 (589)	143	Air volume reported with tubes (without tubes)
Stihl	BR 400	Backpack	N/R	56.5	3.4 hp	476 (624)	180	Blower/Vacuum; Air vol. reported with tubes (without tubes)
Stihl	SR 320	Backpack	N/R	44.9	2.7 hp	385 (589)	205	Blower/Sprayer; Air vol. reported with tubes (without tubes)
Stihl	SR 400	Backpack	N/R	56.5	3.4 hp	420 (624)	230	Blower/Sprayer; Air vol. reported with tubes (without tubes)
Tanaka	TBL-4600	Backpack	69	43	2.5 hp	500	200	
Tanaka	TBL-505	Backpack	69	43	2.5 hp	540	218	
Tanaka	THB-2500	Hand Held	69	24	1.3 hp	304	134	
Toro	BP6900	Backpack	62	41	N/R	370	N/R	
Toro	51539	Hand Held	N/R	electric	7.3 amp	N/R	155	"Air Rake"
Toro	51549	Hand Held	N/R	electric	7.3 amp	N/R	155	"Rake And Vac"
Toro	51586	Hand Held	N/R	electric	7 amp	170	140	"Power Sweep"
Toro	51587	Hand Held	N/R	electric	12 amp	275	210	"Super Blower Vac"
Toro	51589	Hand Held	63	electric	12 amp	260	190	"QuieTech"
Vandermolen	542BTX	Backpack	N/R	40.2	N/R	590	250	"Windmill"
Vandermolen	850BTX	Backpack	70	48.7	N/R	750	225	"Windmill"
Vandermolen	856BT	Backpack	N/R	56.6	N/R	840	225	"Windmill"
Vandermolen	5-11KT	Wheeled	N/R	N/R	N/R	N/R	200	

Brand	Model	Type	Noise Level (dBA)	Engine Displacement (cc)	Engine Power	Air Volume (cfm)	Air Speed (mph)	notes
*Data collected from manufacturer-provided brochures and Internet web sites.			Assumed to have been measured using the ANSI test method	N/R = not reported				

APPENDIX H

RESEARCH NEEDS

RESEARCH NEEDS

Exhaust Emissions

The ARB has an active research program to determine exhaust emissions from engines that it regulates. Existing and future exhaust emission control standards will continue to require that manufacturers reduce emissions from the small off-road engines found in leaf blowers. Staff conducts periodic reviews of technology to determine whether further emission reductions are possible. For example, the ARB has recently awarded a contract to the Southwest Research Institute to conduct research entitled “Particulate Emissions from Marine Outboard Engines, Personal Watercraft and Small Off-Road Equipment.” The objectives relevant to leaf blower technology are (1) to measure the emissions from two-stroke engines used in small off-road equipment, with an emphasis on PM emissions and polycyclic aromatic hydrocarbon levels; and (2) to determine particle size distribution and mutagenic toxicity of the PM. The contractor will obtain and test five engines typically used in leaf blowers or similar off-road equipment, and staff have recommended that engines used in leaf blowers be among those chosen.

In addition to this study, staff has identified investigation into small off-road engine deterioration as an area for future research; engine deterioration causes emissions to increase with engine usage. In general, research into annual usage data, both for the leaf blower equipment and for the operator, would be helpful. The estimated annual usage in the inventory may be lower than actual usage, and may not correlate well with how long an operator, commercial or residential, uses the equipment throughout the year.

Fugitive Dust

ARB staff found a fundamental lack of information on the nature and quantity of fugitive dust blown, or resuspended, by leaf blowers. Empirical data are needed, however, as calculations only go so far. Any study would need to consider a large number of variables, such as substrate, humidity, seasonality, and type of materials being moved by the leaf blower. Ideally, as part of a future research project, one would want to first quantify the emissions in actual use by: (1) inventorying the types of surfaces cleaned by leaf blowers statewide, and by air district, (2) determining the silt loading for surfaces that are cleaned, and (3) performing source testing to determine the amount of PM30, PM10 and PM2.5 entrained in the air, and to determine the "exposure envelope" associated with leaf blower usage. This information could then be used to calculate more accurate estimates of dust associated with leaf blower usage.

In addition to quantifying emissions, it would also be important to determine what is in the dust. This information would not be applicable only to leaf blowers, but would reflect what is in dust that is resuspended by wind from any source. Presently, chemical speciation data are available for sources such as paved and unpaved roadways. For leaf blowers, we should also examine the make-up of dust from lawns, sidewalks, parking lots, and flower beds. In addition to chemical speciation, it would also be useful to analyze the dust for the presence of herbicides, pesticides, bacterial endotoxins, and other toxins.

Noise Emissions

The investigation and reduction of noise emissions is not part of the ARB′s authority or mission. Traditionally, noise control and abatement has been a local function, although a state Office of Noise Control did exist for a short time; the Office was housed within the Department of Health Services. Quantifying noise exposures of landscape and gardening workers might be conducted as a part of a larger ARB effort aimed at better understanding the leaf blower population and annual hours of use. Otherwise, most noise related research would be better conducted by other state agencies.

Quantify the number of Californians affected by noise and noise exposure levels. The purposes of this study would be two-fold: First, to assess the number of workers who are exposed to leaf blower noise, the number of hours they are exposed daily, and their daily noise dose and exposures. Second, to determine the number of people exposed non-occupationally to leaf blower noise, average noise exposures, frequency of exposure (e.g., daily, weekly), and how they are affected (e.g., annoyed, interference with sleep or communication). Agencies potentially responsible for this study would include ARB; the Office of Environmental Health Hazard Assessment; and the California Department of Health Services Occupational Health Branch.

Evaluate hearing loss in gardeners, emphasizing those who use leaf blowers as a part of their work. The purpose of this study would be to evaluate, more specifically, the incidence of noise-induced hearing loss in occupationally exposed gardeners. Non-occupational exposure to noise would also need to be assessed. Agencies potentially responsible would include the California Department of Health Services Occupational Health Branch.

Potential Health Impacts

Exposure data are needed to determine potential health effects, particularly from CO, particulates, and noise. This would include measuring actual doses received by leaf blower operators (professional and homeowner) and the amount of time the dose is received. The Office of Environmental Health Hazard Assessment may be able to assist with preparing an exposure report, as they have prepared reports on exposures to toxic air contaminants

A draft research plan to begin assessment of potential health impacts of leaf blowers on operators and the public-at-large is included herein as a starting point to assess tasks and costs:

Assessing Potential Health Impacts of Leaf Blowers on Operators and the Public-at-Large

This draft, proposed research plan would address two issues related to leaf blower usage in California: First, what is the nature and quantity of fugitive dust resuspended by leaf blower usage; and second, what are the exposures to carbon monoxide, other exhaust emissions, and fugitive dust experienced by leaf blower operators? The proposed research does not include research into noise exposure, although the study could be expanded with outside expert assistance, as ARB does not have a mandate to study noise. The study also would not directly assess exposures experienced by bystanders in the vicinity of someone else using a leaf blower, although the data gathered could be used to make some preliminary estimates regarding these exposures. The estimated cost of the study is $1,100,000.

Task 1 - Population and activity survey. $50,000. Determine the population of leaf blowers, by type (backpack engine-powered, wheeled engine-powered, handheld engine-powered, handheld electric), by air district. Determine usage patterns, how many are used by homeowners and how often, and how many by professional gardeners and how often. Also determine the amount of time each leaf blower is used versus the amount of time each person (including non-operators on a gardening crew) are exposed to leaf blower use. This task would involve the development of a survey instrument and may involve the use of data loggers.

Task 2 - Methodology development for measuring and calculating fugitive dust (particulate matter) emissions and exposure assessment. $50,000. This task would build on previous data on measuring and calculating emissions, but would involve some new methodology as no previous studies have measured fugitive dust resuspended by leaf blowers. As leaf blowers are often used at the same time as other lawn and garden equipment, this task will include differentiating between emissions from leaf blowers and other equipment.

Task 3 - Field study to collect data on exhaust and fugitive dust generation and exposures by operators. $800,000. The study has several facets:

Task 3a - Dosimetry of operators to measure CO and other exhaust emissions exposures. Could also include audiodosimeters if noise dose is being measured. Operators participating in the study would keep journal records of activities while working with lawn and garden equipment.

Task 3b - Measure silt loadings for representative sites based on where leaf blowers are used, during different climate conditions and/or seasons, and in different regions of the state.

Task 3c - Perform fugitive dust emissions sampling and sample collection at selected sites, during selected seasons; data are to be used to estimate both personal exposures, emissions factors, and aggregate daily emission rates.

Task 4 - Sample chemical analysis. $100,000. Actual cost depends on number of samples and chemical species analyzed. Cost assumes 50 samples at $2,000/sample. Study would analyze samples for elements and ions and organic species, such as vegetative detritus, fecal matter, pollen, mold spores, and endotoxins.

Task 5 - Data analysis. $30,000. Analyze data and prepare emissions estimates. Include size-segregated PM emissions for emissions inventory and for personal exposure assessment.

Task 6 - Quality assurance. $30,000. Determine accuracy of subjects in recording leaf blower usage in daily journals, proper use of dosimetry equipment, and chemical and data analyses.

Task 7 - Reporting and final report. $30,000.

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APPENDIX I

FUTURE TECHNOLOGY

AND

ALTERNATIVES

Engine Technologies That Reduce Exhaust Emissions

For the most part manufacturers have met the 1995-1999 emissions standards by calibrating their engines to use less fuel, and improving production practices to include tighter tolerances. With implementation of more stringent standards in the 2000 model year will come more advanced technologies (ARB 1998). Various manufacturers have indicated that they will meet the 2000 model-year standards with either small four-stroke engines that have been specifically designed for light-weight and multi-positional use, two-stroke engines with direct fuel injection, or two-stroke engines with stratified scavenging. Moreover, virtually all manufacturers have indicated that they will provide complying products, though not all have been specific about the technologies they plan to use. The various technologies represent a variety of ideas, but ultimately all would reduce the amount of fuel delivered to the combustion chamber. The technologies are briefly described below.

Four-Stroke Engines. Four-stroke engines possess the advantage that the exhaust stroke expels very little unburned fuel, so engine-out HC emissions are much lower than a two-stroke engine. This is because exhausting the spent gases and refilling the cylinder with a fresh air/fuel charge happens sequentially in a four-stroke engine, but simultaneously in a two-stroke engine. In the past, four-stroke engines have not been able to operate multi-positionally, because of engine lubrication problems, so four-strokes have not traditionally been used in handheld equipment. Ryobi and Honda, however, are two companies that have developed handheld four-stroke engines for the 2000 standards. Honda has indicated that it intends to use its engine in blowers and Ryobi offers attachments that can convert a string trimmer to a blower.

Fuel-Injected Two-Stroke Engines. Fuel injection provides better control of the amount and the timing of fuel entering the cylinder. By limiting the fuel admitted to the amount necessary for combustion, and timing fuel introduction to limit the fuel exiting with the exhaust gases, less unburned fuel exits the engine. The loss of unburned fuel is the primary cause of the high HC emissions from two-stroke engines; up to one third of the fuel going into a conventional two-stroke engine exits the exhaust pipe unburned. Tanaka is a company that has developed a fuel-injected two-stroke engine, partially through funding provided by the ARB's Innovative Clean Air Technologies program.

Stratified Scavenging Two-Stroke Engines. Stratified scavenging refers to a system that prevents mixing of the incoming fuel with the exhaust gas by injecting a layer ("strata") of air between the two. The result is that less of the fresh (unburned) fuel escapes, and HC emissions are dramatically reduced. Test results indicate that the technology can easily meet the 2000 standard. As put into practice by Komatsu Zenoah, manufacturer of the Red Max line of blowers, the stratified scavenging engine retains all the advantages of a conventional two-stroke: light-weight, high power output, and relatively simple design. The result is an engine that operates nearer to the chemically balanced air/fuel ratio, which also translates into improved fuel economy.

Two-Stroke Engine with Compression Wave Technology. This technology involves a compressed-air-assisted fuel injection system that eliminates the unburned fuel during the scavenging process of the exhaust portion of the two-stroke cycle. Engines utilizing this technology retain much of the conventional two-stroke design and hardware, and although the fuel metering system needs to be designed to perform with the engine's needs, it reportedly does not need to provide high precision in timing or in spray quality.

The thrust behind the technology is a compression wave, which causes the fuel and air in the cylinder to be greatly disturbed, in effect functioning as a shock wave. This atomizes the fuel and mixes it more thoroughly with the air. In addition, the compression wave helps keep fuel from sticking to the cylinder. According to the U.S. EPA regulatory impact analysis for its small engine regulatory efforts (U.S. EPA 1999), the system as developed by John Deere Consumer Products includes an "accumulator" which collects and temporarily stores compressed air scavenged from the crankcase. The piston compresses the air in the crankcase on the piston's downward stroke. The fuel injection system uses the piston head to open and close its ports. With respect to engine power, John Deere Consumer Products states that the engine power remains nearly the same as the engine without the technology. The technology is planned for production on John Deere Consumer Products equipment in California in 2000.

Two-Stroke Engines with Catalysts. In addition to the above technologies, some manufacturers currently offer equipment with catalytic converters; in fact, the presence of a catalyst is sometimes used as a marketing feature in Europe. As with an automobile, the catalyst assists the conversion of hydrocarbons and carbon monoxide to more benign compounds.

Sound Reduction Technologies

Leaf blower manufacturers are developing new designs to both reduce the amount of noise from leaf blowers and change the quality of sound to make it less irritating (L. Will, pers. com.). The methods range from quieting the engine noise by insulating the engine compartment to changing the design of the fan. Significant sound comes from the fan itself, and thus new fan designs have the potential to change both the loudness and sound quality.

Electric leaf blowers can be quieter than gasoline-powered leaf blowers because of the absence of the engine noise, but often are just as noisy as gasoline-powered leaf blowers (Appendix G). The Los Angeles City Council requested that its Department of Water and Power develop a quieter leaf blower, and a contract was awarded to AeroVironment. The firm developed a prototype electric, battery-powered blower that should be produced in small quantities for testing late in 1999 or early in 2000 (L. Johnson, LADWP, pers. com.). This blower is discussed more in below.

Methanol-Fueled Leaf Blowers

The use of methanol as a fuel for leaf blowers came about following ordinances to ban the use of "gas-powered" leaf blowers. Some parties have undertaken the development of methanol-fueled leaf blowers as an alternative. However, regulations in effect starting with the 1995 model year require manufacturers to certify that engines meet certain emission standards. The certification process involves documentation of the emissions performance of the engine running on a specific fuel. No manufacturer has yet certified a methanol blower, nor has any manufacturer indicated plans to do so in the near future, thus 1995 and new methanol-fueled leaf blowers operate in violation of California and federal law. The ARB is not currently aware of any such violations. If methanol engines were to be offered, they would need to be certified by the ARB and comply with the same emissions standards as any other engines. Modification of pre-1995 blowers would not need to be certified under the current regulations. Modification of 1995 and newer leaf blowers, however, must be made in accordance with the ARB's aftermarket parts regulations.

The use of methanol also raises some concerns beyond those associated with a gasoline-fueled internal combustion engine. These include flame luminosity, as methanol burns with a pale flame, leading to safety issues, and toxicity. Occupational exposure to methanol through inhalation and skin contact is widespread (U.S. EPA 1998), and exposure would be expected during fueling of leaf blowers. The symptoms of methanol poisoning include nervous symptom dysfunction, damage to the visual system, and even death, and are thought to be due to build of metabolic breakdown products in the body. Most analysts believe that inhaling low concentrations of methanol is not harmful for healthy people, but may be harmful for potentially susceptible populations, such as those deficient in folic acid (Medinsky, et al. 1997).

Electric Equipment

Another technology in current use, particularly for residential applications, is powering the leaf blower with electricity. Electric equipment tends to be less expensive than the equivalent gasoline-powered equipment, with comparable performance on residential products. Staff investigated the products available at several mass market stores, and found that several corded, and one model of non-corded, electric blowers are available. Additionally, AeroVironment, working under the auspices of the Los Angeles Department of Water and Power, has developed a prototype battery-powered blower for commercial use. As many as 1500 pre-production models will be distributed to various gardeners and landscapers to verify its utility for commercial use (L. Johnson, LADWP, pers. com.).

Alternatives to Leaf Blowers

Questions have been asked about the impacts of other methods of street cleaning, such as using a broom or washing down the street with water. Data that were located generally focused on a comparison of the amount of time it would take to clean a given space with leaf blowers versus other equipment, but no controlled, scientific studies were available. For example, ARB was given a press release that quoted a cleaning contractor for the Rose Bowl in Pasadena as stating that cleaning the Rose Bowl after a game takes 1,000 to 1,500 man-hours unless they use leaf blowers, in which case the job takes about 720 man-hours (IME 1999). Other short tests have been conducted, comparing cleaning time using a broom versus a leaf blower (Wolfberg, pers. com.). Finally, a City of Whittier report includes a chart comparing cleaning efficiencies of a "giant vac," back pack blower, broom, and "hose down," but no information were available as to the methods used to collect or analyze the data (Hamano 1992). In short, data were not of sufficient quality to permit an evaluation of the efficiency of alternatives to leaf blowers.

Similarly, no data could be located regarding fugitive dust resuspended by alternatives, such as brooms or vacuums or the amount of water that would be used for cleaning, in lieu of leaf blowers. The Los Angeles Department of Water and Power collected very limited data on sound levels of raking. One measurement of noise from raking was about 66 dBA at 50 ft (LADWP 1998), but it is intermittent noise, as compared to the continuous noise of a leaf blower, and a direct comparison is not possible without more data. Further study would be required to fully characterize such alternatives to leaf blowers as vacuuming, sweeping, raking, and hosing.

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APPENDIX J
EXPOSURE SCENARIOS FOR
LEAF BLOWER EMISSIONS AND USAGE

Exposure Scenarios for Leaf Blower Emissions and Usage

Exposure scenarios are presented that describe potential exposures resulting from the emissions from two types of leaf blowers. Commercial-type blowers have an average power rating of 3 hp and residential-type blowers have an average power rating of 0.8 hp. Staff has estimated the amount of still air in which the emissions from 10 minutes of leaf blower operation would need to be mixed in order to prevent a local, transitory exceedance of the relevant national ambient air standards. These are worst case scenarios, which assume that all emissions from the blower in the specified time-frame remain in the breathing zone of the operator. The best case would be one in which all emissions and fugitive dust are blown out of the immediate area, resulting in no exposures to operators or bystanders. Actual exposures would vary greatly, and depend on many factors, including wind, temperature, humidity, use of protective gear, surface being cleaned, walking speed of operator, and proximity of bystanders.

Based on the estimated emissions, the amount of air that would be needed to mix with the emissions to avoid exceeding the National Ambient Air Quality Standards (see Appendix C) has been calculated. The PM standards, however, are not generally short term exposure standards, but have been selected as the best surrogate for short term exposure standards. The estimates for exhaust and fugitive dust exposures, then, have no objective significance, in and of themselves, but are presented for comparative purposes.

A. Commercial Leaf Blower Usage

Ten minutes is considered to be a reasonable estimate of the time it might take to clean an average yard by an experienced leaf blower operator (Table 1). If the actual usage time is greater or less, the data can be adjusted accordingly. Also calculated are emissions of leaf blowers complying with yr 2000 and later standards (Table 2). The difference between the data is that Table 1 presents actual exhaust emissions of a 1999 population, based on certification and test data; Table 2 uses a future regulatory level, which will not be reflected in the population of leaf blowers for several years until all leaf blowers produced prior to 2000 have been removed from use. Carbon monoxide levels are higher because the regulatory level is higher than what is being achieved in practice by current leaf blower engines. Also presented in Table 1 are fugitive dust emissions for 10 minutes, which are not repeated in other tables, as the data do not change. The data illustrate a worst case scenario, as discussed above.

Table 1. Leaf Blower Emissions and Mixing Space for the Operator, 3 hp average and 50% load factor, 1999

	Exhaust Emissions, g/bhp-hr	**Exhaust Emissions, g/10 min**	**Amount of Mixing Space Necessary to Not Exceed the NAAQS**[2]
Hydrocarbons	132.84	33.21	NA[3]
Carbon Monoxide	282.35	70.59	1765 m^3
Particulate Matter	4.29	1.07	7133 m^3
Fugitive Dust	---	8.1 - 171.8	Varies

Table 2. Leaf Blower Emissions and Mixing Space for the Operator, 3 hp average and 50% load factor, Based on 100% compliance with yr 2000 standard

	Exhaust Emissions, g/bhp-hr	**Exhaust Emission, g/10 min**	**Mixing Space Necessary to Not Exceed the NAAQS**
Hydrocarbons + NOx	54	13.5	NA
Carbon Monoxide	400	100	2500 m^3
Particulate Matter	1.5	0.375	250 m^3

For CO (Table 1), the 71 g emitted in ten minutes would require mixing in 1765 m^3 of air in order avoid exceeding the NAAQS 1 hr standard for CO of 35 ppm, assuming that all of the CO remains in the immediate area, and that the person being exposed breathes this air for 1 hour. The amount of air in 1765 m^3 is comparable to the amount of air that would fill a cube 12.1 m, or 39.6 ft, on each side. As discussed above, this estimate does not permit a determination of the health impacts of the exposure to CO. These data, however, do suggest that the relatively large amount of CO emitted directly into the air space surrounding the operator could result in the inhalation of an unhealthful dose. Staff recommends that further research is warranted to determine exposures and related health impacts from small, two-stroke engine emissions.

For the PM10 (Table 1) directly emitted from exhaust emissions, the air space necessary for mixing in order not to exceed the 24-hour standard for PM10 is larger than that for CO,

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2National Ambient Air Quality Standard

3No relevant NAAQS exists for hydrocarbons as this is a catch-all category for many chemicals.

comprising an amount of air equivalent to a cube 19.2 m, or 63.2 ft, on each side. The yr 2000 standards will result in a significant reduction in directly emitted PM10.

PM emissions from the blown dust, however, dwarf the PM emissions from exhaust. Using the low median emissions factor of 8.1 g/10 min, we find that a cube of air 37.8 m, or 124.0 ft, on each side would be equivalent to the 54,000 m^3 of air that would be needed to dilute the PM10 sufficiently to avoid exceeding the 24-hour national ambient air quality standard. The high median emissions factor 171.8 g/10 min yields 1,145,333 m^3 of air required to dilute the PM10 (104.6 m cube).

B. Homeowner Leaf Blower Usage

Using the same methods as above produces the emissions shown in Table 3. As discussed above, this exposure model assumes a worst case in which there is no dispersion of pollutants out of the immediate area. Actual exposures would be somewhere between the worst case and zero. Table 4 presents emissions data based on the yr 2000 control levels. Fugitive dust emissions are not repeated from Table 1 in this section, as they do not change.

Table 3. Leaf Blower Emissions and Mixing Space for the Homeowner, 0.8 hp average and 50% load factor, 1999

	Exhaust Emissions, g/bhp-hr	Exhaust Emissions, g/10 min	Mixing Space Necessary to Not Exceed the NAAQS
Hydrocarbons	141.82	9.45 g	NA
Carbon Monoxide	297.93	19.86 g	497 m^3
Particulate Matter	3.6	0.24 g	1,600 m^3

Table 4. Leaf Blower Emissions and Mixing Space for the Homeowner, 0.8 hp average and 50% load factor, Based on 100% compliance with yr 2000 standard

	Exhaust Emissions, g/bhp-hr	Exhaust Emissions, g/10 min	Mixing Space Necessary to Not Exceed the NAAQS
Hydrocarbons + NOx	54	3.6 g	NA
Carbon Monoxide	400	26.67 g	666.7 m^3
Particulate Matter	1.5	0.1 g	66.7 m^3

For comparison, for CO (Table 3) the mixing space necessary to avoid exceeding the standards is equivalent to a cube of air 8 m, or 26 ft, on each side. For fugitive dust (Table 3), 1.8 g of PM10 emitted in ten minutes would need to be mixed in a volume of 12,000 m^3 of air in order to avoid exceeding the 24-hour standard for PM10. This is an amount of air equivalent to a cube 22.9 m, or 75.1 ft, on each side. As with the commercial exposure, this is a potentially hazardous exposure, but because the homeowner is likely using leaf blowers for a very short time each week, the concern is much lower than for commercial gardeners. Still, staff would recommend that even homeowners wear a dust particulate filtering face mask.

APPENDIX K

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