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Noise exposure among federal wildland fire fighters

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Abstract: Wildland fire fighters use many tools and equipment that produce noise levels that may be considered hazardous to hearing. This study evaluated 174 personal dosimetry measurements on 156 wildland fire fighters conducting various training and fire suppression tasks. Noise exposures often exceeded occupational exposure limits and suggest that wildland fire fighters may be at risk of developing noise-induced hearing loss, particularly those operating chainsaws, chippers, and masticators. The authors recommend a comprehensive approach to protecting these fire fighters that includes purchasing quieter equipment, noise and administrative controls, and enrolling these fire fighters into a hearing conservation program.

[SKL]

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1. Introduction

Structural (urban) and wildland (non-urban) are the two primary modes for fire fighting. Structural aims to protect buildings and structures, and non-urban or wildland fire fighting, aims to suppress grass, brush, or forest fires. Wildland fire fighting is considered a high-risk emergency response occupation requiring considerable physical and psychological demands. Wildland fire fighters often work 12 to more than 16 h per shift for up to 14 consecutive days over a 3- to 9-month period [U.S. Department of Agriculture (USDA), 2008]. Wildland fire fighting requires personnel from a variety of different agencies including federal, state, tribal, and local government agencies; contracting agencies; prison-operated crews; and in some cases the military (e.g., the National Guard). The largest proportion of the workforce is likely to be volunteers from local fire departments. In response to a 2010 National Fire Protection Association (NFPA) survey, 86% of the 26 000 local fire departments, which are staffed with more than 1.1×10^6 fire fighters, had wildland fire fighting duties, and many were staffed primarily by volunteers [National Fire Protection Association (NFPA), 2011]. The U.S. Department of Interior and the U.S. Forest Service also staff more than 19 000 career and seasonal federal wildland fire fighters (Ted Mason, National Wildfire Coordinating Group, Risk Management Committee, February 2016; George Broyles, US Forest Service Technology and Development Program, July 2016).

Wildland fire fighters often have extreme exposures to many physical agents and occupational hazards (Britton *et al.*, 2013). Similar to other high-risk occupations, research efforts and occupational safety and health programs have historically focused on identifying and preventing acute injuries and exposures, but less emphasis has been placed on research and prevention programs relating to chronic diseases or injuries such as occupational noise-induced hearing loss (NIHL).

Hearing loss is one of the most common work-related illnesses in the United States. NIOSH estimates that 22×10^6 U.S. workers encounter noise exposures loud enough to be hazardous (Tak *et al.*, 2009). Although noise exposures and hearing loss among structural fire fighters have been well studied (Hong *et al.*, 2008) and

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documented [National Institute for Occupational Safety and Health (NIOSH), 2013], wildland fire fighters, primarily because of their seasonal and transient work schedules, have not received the same attention, nor have their noise exposures been empirically researched and studied. The sources of noise are quite different during wildfire suppression operations. Wildland fire fighters may be repeatedly exposed to known sources of noise including chainsaws, aircraft, wood chippers, audio equipment, hand and engine pumps, heavy equipment (e.g., bulldozers), and ambient noise from the wildfire itself. Although equipment and vehicles used in wildland fire suppression activities are similar to those used by other occupations, some of the unique characteristics of wildland fire fighting may increase their overall noise exposure and potential risk of hearing loss. For example, wildland fire fighters have a wide variability in work activities during and between workshifts, work atypically long shifts, and do not receive the auditory rest between shifts that would normally occur with other occupations. In addition to noise, wildland fire fighters' potential exposure to vibration from chainsaws and power tools and their exposure to carbon monoxide and other combustion byproducts from equipment and fires may have ototoxic effects that could exacerbate hearing loss (Iki *et al.*, 1986; Lees, 1995). Noise exposure may have other non-auditory effects including increased heart rate, fatigue, and reaction time, and reduced concentration (Tomei *et al.*, 2009). Reduction in hearing abilities not only increases the likelihood of miscommunication, but, coupled with the non-auditory health effects, can increase risk of injury and overall situational awareness and lessen the fire fighter's ability to react to the hazards on the fireline, which can be life threatening in such hostile environments (Neitzel *et al.*, 2015). Figure 1 shows wildland fire fighters during various fire suppression activities.

In an effort to address noise exposures within this population, the United States Forest Service' Technology and Development Program initiated a 3-year study to assess wildland fire fighters' noise exposures during training and fire suppression tasks and to identify which jobs put these fire fighters at increased risk for NIHL. This paper reports on the initial results from the study, characterizes the most hazardous noise sources and job tasks based on personal dosimetry measurements, and provides specific and practical recommendations for protecting the hearing health of these fire fighters.

2. Methods

Noise exposure measurements were collected at 10 different fire locations during the 2014–2015 fire seasons. Locations were identified based on the National Situation Report of large daily fires in the United States. Once a location was selected, researchers contacted the commanding official at the fire to request permission to interact with fire crews and equipment operators, and collect personal noise dosimetry measurements



Fig. 1. (Color online) Wildland fire fighters during various fire suppression activities.

at the fire. To assess noise exposures during training and other non-fire activities, measurements were also conducted during pre-season chainsaw certification, at three airtanker bases during support activities for large wildland fires, and at a ranger station while fire fighters operated various equipment (e.g., leaf blowers, weed whip) in preparation for prescribed burns.

Personal noise dosimetry was conducted with 3M Edge5 (3M Personal Safety Division, Oconomowoc, WI) datalogging noise dosimeters, which conformed to the American National Standards Institute (ANSI) standard (ANSI, 1997). Dosimeter parameters were set to measure according to the Occupational Safety and Health Administration (OSHA) requirements for comparison with the permissible exposure limit (PEL) and also the National Institute for Occupational Safety and Health (NIOSH) guidelines for comparison with their recommended exposure limit (REL). Occupational regulations and standards are established to protect workers against the health effects of exposure to hazardous substances and agents when certain values (or limits) are reached. NIOSH establishes RELs for various hazards on the basis of the best available science and practice. The REL for noise is 85 decibels, using the A-weighting frequency response and a 3-dB exchange rate and over an 8-h average, usually referred to as time-weighted average (TWA); exposures at or above this level are considered hazardous (NIOSH, 1998). OSHA sets legally-enforceable PELs that require employers to take actions to reduce worker exposures. The OSHA PEL for noise is 90 dBA as an 8-h TWA based on a 5-dB exchange rate (OSHA, 1983). Both NIOSH and OSHA use the 80-dBA threshold level for calculating their respective REL and PEL.

Dosimeters were attached to the fire fighters' outer garments in their hearing zone and placed in a way that did not interfere with their communication or come in contact with other gear or equipment. Fire fighters were instructed to avoid contact with the dosimeters' microphone and were observed throughout the assessment to ensure the dosimeters were not in contact with clothes or equipment to avoid extraneous noise data. In addition, the dosimeters' microphones come equipped with wind-screens to reduce the effects of wind and environmental conditions on the collected data. All dosimetry data were downloaded to a computer for analysis after each shift using the QuestSuite Professional II software (3M Personal Safety Division, Oconomowoc, WI) and inspected for any potential errors that could have been introduced during the noise assessments. The dosimeters were factory calibrated within the previous year and field-calibrated before and after each workshift. Field calibrations were conducted on the survey date using a 3M AcoustiCAL AC300 calibrator (3M Personal Safety Division, Oconomowoc, WI). Researchers observed the fire fighters during fire suppression and training exercises and documented the occupational and environmental variables that could have contributed to their overall noise exposure during the entire workshift.

3. Results

The 174 full-shift personal noise dosimetry measurements were conducted on 156 fire fighters in 14 different wildland fire fighting job categories. A workshift includes the entire period during a day that a fire fighter is considered in paid status, including time on the fireline, morning briefings, traveling to/from a fireline, staging, and any breaks in between. Shift lengths ranged 5–15 h. Repeat measurements were conducted on 21 fire fighters conducting similar tasks on different days. Ninety-four percent ($n=146$) of the fire fighters sampled were male with an average age of 37.8 years (range, 21–77 years), and most of the fire fighters ($n=110$) had six or more years fire fighting experience. The number of wildland fire fighters examined in this study and their specific job tasks are shown in Table 1.

The results of this study showed wildland fire fighters are often exposed to noise levels that exceed occupational noise exposure limits. Table 2 shows a summary of the personal dosimetry measurements, on the basis of NIOSH REL and OSHA PEL measurement criteria, collected on wildland fire fighters performing a variety of tasks and activities. Since some of the workshifts exceeded the normal 8-h workshift for which occupational time-weighted averages are calculated, Table 2 tries to delineate between the average level over the entire shift (which can last up to 14–15 h) and the TWA which is based on 8 h. For durations other than 8 h, OSHA uses the term Lavg (average level) and NIOSH uses the term Leq (equivalent sound level) to report averaged noise levels. Those values are reported as the mean average noise levels \pm one standard deviation.

Table 1. Sampling and demographic breakdown of wildland fire fighters numbers per activity/task.

Job Description Activity/task	Typical work activities and tasks	Number of measurements	Age range (years)	Average workshift (hours:minutes)	Total measurement time (hours)
All-terrain buggy (ATB) operator	Operates four-wheel drive ATBs to transport supplies or scout a fireline.	14	20–64	12:00	167.54
Bulldozer operator	Operates a bulldozer typically used for cutting a fireline.	10	32–63	12:29	124.55
Engine operator (ENOP)	Fire fighters who operate a pump on a fire engine.	22	24–51	12:56	284.35
Equipment operator	Operates any equipment other than dozers, masticators, chippers, and excavators.	20	23–77	11:53	237.45
Heavy equipment boss (HEQB)	Works with various types of heavy equipment (e.g., bulldozers, feller bunchers, excavator) and identifies the heavy equipment operator's route.	10	27–58	12:12	121.56
Helitack crew member	Work around helicopters performing a variety of tasks, such as marshalling the helicopter during takeoff or landing and loading passengers and supplies.	28	26–60	12:08	336.30
Helicopter pilot	Operates a helicopter performing a variety of different tasks including transporting passengers and supplies and dropping water or retardant on the fire.	4	34–65	13:05	52.21
Leaf blower operator	Operates leaf blowers to remove leaves to create a fireline/fuelbreak or clear out area around trees in advance of an approaching fire or before a prescribed burn.	5	23–31	9:14	37:02
Masticator/ chipper operator	Operates a masticator or chipper to grind up small trees and brush.	7	21–59	11:33	80.53
Pump operator	Operates a variety of pumps including portable and Mark 3 pumps.	3	35–53	13:57	41.53
Sawyer/swamper	Operates chainsaws during a variety of activities. A sawyer operates a chainsaw during fire suppression or prescribed fire preparation. The swamper works in conjunction with sawyer, removing cut branches and brush, and acting as lookout. Sawyers/swampers often switch roles with each chainsaw fuel cycle.	23	22–62	12:03	277.02
(UTV)/buggy operator	Operates or rides on UTVs in wet, swampy, areas. UTVs typically transport crews, water, and supplies.	15	27–58	9:53	148.08
Water tender driver	Operates water tender vehicles to supply water to engines or stationary holding tanks.	8	21–71	12:45	102.03
Weed whip operator	Operates weed whip to clear grass from around trees and buildings.	5	29–46	8:14	32:00

Occupational standards specify a maximum allowable daily noise dose, expressed in percentages. For example, a person exposed to an average exposure of 85 dBA using NIOSH criteria or 90 dBA per the OSHA Standard over an 8-h work shift will have a daily noise dose of 100%. The noise dose is based on both the sound exposure level and the duration of exposure, so for each increase of 3-dB (NIOSH) or 5-dB (OSHA) in noise levels, the allowable duration of the exposure is cut in half, to have an equivalent noise dose. Some of the fire fighters in six of the 14 job categories we monitored had noise exposures that exceeded the OSHA PEL. In contrast, one to all of the fire fighters in all 14 job categories has noise exposures exceeding the NIOSH REL.

Table 2. Summary of wildland fire fighters noise exposures based on OSHA and NIOSH occupational exposure limits.

Job description Activity/task	OSHA PEL (90 dBA)			NIOSH REL (85 dBA)		
	Lavg (dBA)	TWA (dBA)	Dose (%)	Leq (dBA)	TWA (dBA)	Dose (%)
ATB operator	71.9 ± 6.8	59–85	1–51	84.3 ± 3.5	79–93	15–637
Bulldozer operator	78.6 ± 21	43–113	0–1,995	89 ± 11.7	72–112	5–51,804
Engine operator	67.6 ± 9.4	52–82	1–73	81.7 ± 5.5	75–97	3–503
Equip operator	72.7 ± 13	56–94	1–144	84.7 ± 7.1	76–100	10–3,522
Helitack crewmember	64.3 ± 11.9	47–91	0–111	80 ± 7	71–102	4–1,486
Helicopter pilot	86.8 ± 2	88–92	79–136	90.7 ± 1.1	92–94	490–749
Heavy equipment operator	62.3 ± 6.5	55–79	1–22	79 ± 4	75–90	3–338
Leaf blower	80.8 ± 2.5	78–84	18–43	88.4 ± 1.9	87–91	142–377
Masticator/chipper operator	92.4 ± 5.3	88–103	72–583	97.8 ± 4	94–105	891–10,871
Pump operator	78.9 ± 4.1	78–85	19–53	89.1 ± 3.5	87–95	177–950
Sawing/swamping	89.5 ± 5.2	80–103	26–606	96.9 ± 3.6	91–106	280–9,250
UTV/buggy operator	73 ± 5.6	61–83	4–38	84.2 ± 3.8	76–93	4–202
Water tender operator	66.1 ± 8.4	54–79	1–23	80.9 ± 3.9	76–87	14–170
Weed whip operator	80.7 ± 3.8	77–86	15–58	87.6 ± 2.5	85–91	99–401

Overall, 85 of the 174 measurements were above the NIOSH maximum allowable daily dose. Almost all masticator/chipper operators, pilots, pump operators, leaf blowers, sawyers and swampers, and bulldozer operators had TWAs that exceeded the NIOSH REL of 85 dBA (masticators/chippers TWAs reaching 105 dBA, sawyers and swampers TWAs reaching 106 dBA, and bulldozer operator TWAs reaching 112 dBA). Fire fighters exposed to TWA of 105–106 dBA would exceed their maximum daily limit in just 4–5 min. At 112 dBA, a bulldozer operator exceeded 100% noise dose in 56 s. Bulldozer operators received the highest possible daily noise dose, some exceeding the OSHA maximum daily dose by 20-fold and the NIOSH maximum daily dose by 500-fold. It is interesting to note that four of the bulldozer operators had TWAs well below the NIOSH REL, most likely because they operated out of closed or environmental cabs which isolated the bulldozer operator from much of the noise generated from the heavy equipment.

Figure 2 shows the percentage of fire fighters' personal dosimetry measurements that exceeded NIOSH REL or the OSHA PEL based on their specific activities or tasks. Since NIOSH REL and OSHA PEL are based on different criteria the NIOSH REL is considered more protective and thus more of the dosimetry measurements are likely to exceed the NIOSH REL than the OSHA PEL. All of the sawyers/swampers, helicopter pilots, pump operators, masticators/chippers, and leaf blowers that were monitored exceeded the NIOSH REL. Almost 90% of masticators/chippers and more than 70% of sawyers/swampers also exceeded the OSHA PEL.

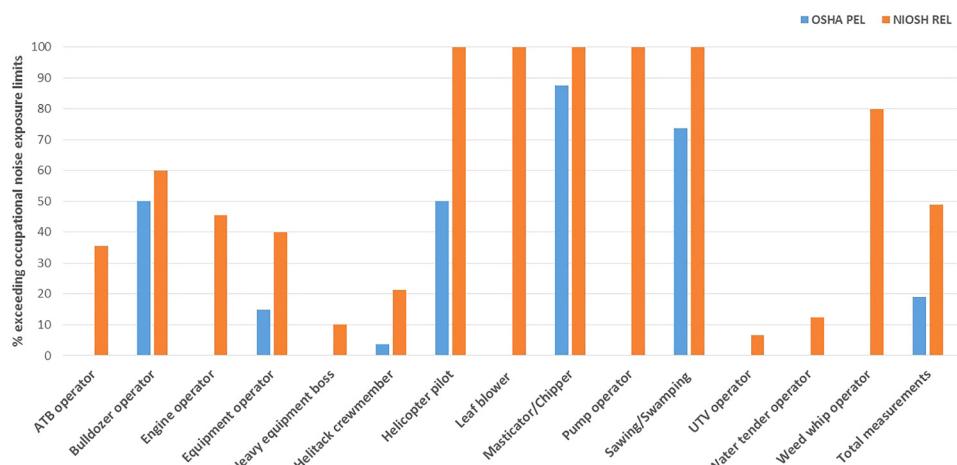


Fig. 2. (Color online) Percentage of dosimetry samples exceeding the OSHA PEL and NIOSH REL per work category.

4. Discussion

Several agencies are involved in wildland fire suppression operations in the United States, and policies and procedures to assess noise exposure and prevent hearing loss vary between agencies. For example, the U.S. Forest Service has a hearing conservation program, but wildland fire fighters, in general, are exempt because their occupation is not included in the U.S. Forest Service hazardous noise occupational category (USDA, 2005). However, pilots and heavy equipment operators, both occupational categories that participate in wildland fire suppression, are considered hazardous noise occupations and are required to participate in baseline audiograms, annual audiograms, and hearing conservation training programs. Although wildland fire fighters, except those who are pilots and heavy equipment operators, may not be required to participate in a hearing conservation program, the U.S. Forest Service does require the use of hearing protection for all their workers when noise levels exceed 85 dBA. Additionally, the U.S. Forest Service provides hearing protection devices to their wildland fire fighters for use. It is not clear however, whether fire fighters consistently use hearing protection, wear them correctly, or whether they provide the appropriate level of attenuation.

Noise exposures among wildland fire fighters vary due to their tasks, shift length, and number of days performing wildfire suppression tasks using the equipment evaluated in this study. Our measurement show that even within the same job, noise exposure can vary substantially. Our analyses also show that fire fighters in all of the jobs we monitored could have noise exposures exceeding the NIOSH REL. Furthermore, all of the fire fighters in the masticator/chipper, pump operators, sawing or swamping, leaf blowing, and helicopter pilot jobs exceeded the NIOSH noise exposure REL. Overall, 48% of wildland fire fighters' dosimetry measurements exceeded the NIOSH REL for noise exposure, and 18% of fire fighters reached 100% noise dose in a less than 30 min. Some fire fighters received a noise dose 500 times greater than the maximum daily noise dose in a single shift. As our data show, most wildland fire fighters are unlikely to experience high noise exposures on every work shift. However, the data obtained in this study do suggest that wildland fire fighters may be exposed to high levels of noise, very regularly, and on any given workshift while performing a variety of different tasks.

Although the equipment used during wildfire suppression (chainsaws, bulldozers, engine pumps, etc.) are not any different as far as noise emission from equipment used in other occupations, the specific environment that wildland fire fighters work in makes their exposures unique and potentially more hazardous. The unique wildfire work environment must be taken into consideration when developing plans and programs to reduce wildland fire fighters' noise exposures. The occupational hierarchy of controls approach that works well to mitigate industrial noise exposures may not be appropriate or feasible for reducing wildland fire fighters' overall noise exposures. Additional studies are needed to examine different and specific approaches and to evaluate their effectiveness for this specific population.

On the basis of our study results, wildland fire fighters are at risk of noise-induced hearing loss. To prevent fire fighters from developing a hearing impairment, NIOSH recommends that all wildland fire fighters be enrolled in a hearing conservation program and that fire agencies establish and maintain fire service specific hearing loss prevention programs. These programs should include the following elements:

- Implement engineering and administrative controls to limit fire fighters' noise exposure from equipment or the work environment. For instance, there are several studies and available research on effective engineering noise controls for chainsaws, power tools, bulldozers. Agencies should consult NIOSH and OSHA websites for information on noise controls and their effectiveness and consider incorporating noise emission limits in their purchasing agreements for new equipment. The NIOSH "Buy Quiet" (NIOSH, 2014) program encourages a purchaser to compare the noise emission levels of different models of equipment and, whenever possible, buy the quieter model.
- Educate fire fighters, especially new employees, about harmful noise levels from various tasks and equipment, the effects of noise exposure and risk for hearing loss, the importance of and how to properly use their hearing protection devices, and the importance of audiometric testing. This includes incorporating information into commonly used wildland fire fighting training sites/materials such as Six Minutes for Safety; the Incident Response Pocket Guide; and even the Standards for Survival, if possible.
- Monitor noise levels regularly and when new equipment and tasks are introduced using personal dosimetry for full shift measurements and sound level measurements, preferably according to the more protective NIOSH criterion, to document tasks and events that generate the highest noise exposures.
- Conduct baseline (pre-employment) and annual audiometric testing of all personnel at all wildland fire fighting agencies, with results explained.

- Require fire fighters involved in tasks that exceed the NIOSH REL to wear hearing protection.
- Limit workers' exposure time by rotating individuals involved in tasks that may generate the highest noise exposure.
- Provide fire fighters with appropriate hearing protection devices, especially electronic devices that are designed specifically for fire fighters and provide enhanced communication capabilities while also blocking harmful noise. Fire fighters should be fit-tested to ensure hearing protection devices are selected and work properly using commercially available fit-test systems. Fit-testing allows for easy and accurate measurement of hearing protection effectiveness as the devices are used in the field.
- Update the USFS Health and Safety Handbook to include additional specific information about noise and the potential for noise induced hearing loss among fire fighters.

5. Conclusion

This study evaluated noise exposures of 156 wildland fire fighters and obtained more than 174 different personal noise dosimetry measurements. The results showed that wildland fire fighters participate in a variety of different tasks with noise levels that present a risk of NIHL and other associated health and safety hazards. It is evident that an increased emphasis on noise assessment and hearing loss prevention is warranted among this emergency responder workforce, since most wildland fire tasks can be considered hearing critical, and NIHL may seriously impact a wildland fire fighter's ability to do his or her job safely—or even at all. The authors recommend fire agencies implement the specific and practical recommendations for protecting the hearing health of these fire fighters. In addition, the authors recommend additional studies to examine targeted approaches to mitigate risk among fire fighters with highest exposures.

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The findings and conclusions in this study are those of the authors and do not necessarily represent the official position of the U.S. Forest Service or the National Institute for Occupational Safety and Health.

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