International Journal of Hygiene and Environmental Health xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

Exposure to naturally occurring mineral fibers due to off-road vehicle use: A review

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ARTICLE INFO

Article history:
Received 28 February 2017
Received in revised form 12 July 2017
Accepted 13 July 2017

Keywords:
Off-road vehicle
Dust
Naturally occurring asbestos
Amphibole
Erionite

ABSTRACT

Background: The use of off-road vehicles (ORVs) is a popular source of outdoor recreation in the United States. While personal injury has been the focus of most epidemiologic investigations regarding ORV use to date, other health effects associated with ORV use have not been adequately examined. ORVs have been designed to operate in rugged, unpaved terrain, and ORVs can produce copious amounts of fugitive dust. ORV use in geographic regions with naturally occurring asbestos (NOA) and erionite (NOE) may result in the liberation of these minerals from underlying rocks and soil, which may put ORV participants at risk to potentially hazardous inhalation exposures.

Methods: A comprehensive narrative review of existing literature and reports relevant to off-road recreation and mineral fiber exposure was conducted. Manuscripts and reports included in the review were limited to those that contained quantitative data regarding concentrations of mineral fibers recorded during vehicular traffic on an unpaved road and publication in a peer-reviewed journal, official report composed by a government agency, or a report generated under the endorsement of a government agency. In addition, the potential public health impact of ORV use in regions with NOA/NOE was estimated by calculating the proximity of known mineral fiber occurrences to areas of ORV use.

Results: A total of 15 publications met inclusion criteria. Exposures to NOA/NOE observed from personal sampling in the included studies ranged from less than 0.01–5.6 f/cc. ORV position while riding in a group and vehicle speed were frequent determinants of measured concentrations. Multiple studies also suggest that children may experience higher exposures to mineral fibers in comparison to adult ORV riders. Information on ORV trails and 665 known occurrences of NOA/NOE was available for five states located in the western United States. Of these 665 known occurrences, approximately 80% (n = 515) were located within 20 miles of an ORV trail, and nearly a third were located within one mile.

Conclusions: Individuals who operate ORVs in regions where NOA/NOE is a component of the underlying soil or unpaved road may experience elevated exposures to mineral fibers. Given the prevalence of ORV trails in close proximity to these natural fiber occurrences, epidemiologic and surveillance studies of individuals who frequently engage in ORV use are recommended. Public health initiatives should concentrate on increasing awareness of these risks, allowing ORV users to make informed choices and take appropriate measures to limit these risks where possible.

Abbreviations: ORV, off road vehicle; NOA, naturally occurring asbestos; NOE, naturally occurring erionite.

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http://dx.doi.org/10.1016/j.ijheh.2017.07.003
1438-4639/

1. Introduction

The use of off-road vehicles (ORVs), including four wheel drive vehicles, all-terrain vehicles (ATVs), motorcycles, and other vehicles designed for off-highway use, is among the most popular outdoor activities in the United States (U.S.). In a report by the National Survey on Recreation and the Environment (2005–2007), an estimated 44 million Americans age 16 and older engaged in recreational activities involving ORVs within the past year (Cordell et al., 2008). Children were not included in this random-digit-dialed household telephone survey, and therefore, the number of Americans that use ORVs recreationally is likely higher. While the prevalence of ORV use among children and adolescents is unknown and likely varies by geographic region, one school-based survey in Iowa of 4684 children aged 11–16 found that more than 75% of the participants engaged in ORV use (Jennissen et al., 2014). ORVs are also used occupationally, and an industry study of ATV owners found that 21% of owners used ORVs for work or chores (United States Government Accountability Office, 2010).

Most epidemiologic studies and public health awareness concerning ORVs has focused on injuries and deaths sustained from their use (Brandenburg et al., 2007; Cvijanovich et al., 2001; Denning et al., 2014; Larson and McIntosh, 2012). In 2013, an estimated 99,600 people sought care at an emergency department for injuries experienced as a result of ATV use, and nearly a quarter of these injuries occurred in children (Consumer Product Safety Commission, 2015). In 2014, there were a reported 959 fatalities resulting from ORV use (Center for Disease Control and Prevention, 2015). Surveillance studies and efforts toward injury prevention are certainly warranted. There are, however, additional risks associated with ORV operation, which include inhalation exposure to fugitive dust (Buck et al., 2013; Goossens and Buck, 2009a; Goossens et al., 2012; Padgett et al., 2008).

Off-road driving on unpaved surfaces can significantly increase the amount of total suspended particles, including both PM10 and PM2.5 (particulate matter <10 μm and <2.5 μm in aerodynamic diameter, respectively) (Goosens and Buck, 2014; Goossens and Buck, 2009a, 2009b; Williams et al., 2008) due to dust generation by shearing force and air turbulence (Goosens and Buck, 2014; Williams et al., 2008). Case studies of fugitive dust emissions from ORV use have identified vehicle type and speed, as well as soil characteristics, to be important factors in dust emissions (Goosens and Buck, 2014; Goossens and Buck, 2009a, 2009b; Williams et al., 2008), and the contents of the resulting dust reflects the composition of the soil (Goossens et al., 2015; Soukup et al., 2012). Some of these airborne particles can be elongated minerals that meet the dimensional criteria used to identify asbestos fibers, which we refer to as "fibers" in this review. In regions where they are naturally occurring, fibers of serpentine or amphibole asbestos or potentially hazardous fibers of other minerals, such as the zeolite erionite, may become a component of these generated dusts. Asbestos minerals occurring as a natural constituent of rocks and soils have been identified in the United States, most prominently in the West (Harper, 2008). Collectively, these materials have been referred to as naturally occurring asbestos (NOA). The fibers released by disturbing NOA may include hazardous mineral fibers that fit current U.S. regulatory definitions of asbestos (e.g. chrysotile) and others that may not (e.g. winchite or richterite). Erionite, an unregulated zeolite mineral, is also naturally occurring (NOE). Erionite additionally bears similar properties to asbestos, and inhalation of erionite fibers has been associated with malignant mesothelioma and other pulmonary diseases (Carbone et al., 2011; Ryan et al., 2011; Van Gosen et al., 2013).

In geographic regions where ORV use and NOA/NOE intersect, inhalation of fugitive dusts containing mineral fibers during vehicular travel on unpaved roads may be an exposure pathway of particular importance. Thus, the purpose of the current investigation is to examine the potential for airborne NOA/NOE fiber exposures associated with ORV activities on contaminated soils and gravels. Herein, we 1) review the existing literature on mineral fiber exposures resulting from vehicular travel on unpaved surfaces and, 2) examine the spatial relationship between known deposits of NOA/NOE in the United States and ORV trails.

2. Methods

A comprehensive search of published studies on ORV use and mineral fiber exposure was conducted using the MEDLINE database of the US National Library of Medicine accessed via PubMed and the Web of Science. The following keywords were included in the search: 'fiber', OR 'asbestos' OR 'erionite' OR 'amphibole' OR 'zeolite' OR 'dust') AND ('off-road vehicle' OR 'off-highway vehicle' OR 'ATV' OR 'recreational' OR 'traffic'). In addition, internet searches with these same keywords were conducted to identify reports and publications not available on either PubMed or Web of Science. Finally; personal communications with experts in the field identified additional reports. Publications that reported personal or stationary sampling results obtained during vehicular travel on an unpaved surface; either in the form of airborne concentrations or fibers in settled dust samples; were reviewed. An additional inclusion criterion was publication in a peer-reviewed journal or official report created by (or on behalf of) a government agency. The sampling results reported by these publications were synthesized and represent a narrative review of the available literature.

In order to visualize and identify locations of potential overlap between ORV use and NOA/NOE occurrences, known locations of NOA and NOE were overlaid with areas of ORV activity using geographic information systems (GIS). All GIS analyses were conducted using ArcGIS software (ESRI, Redlands, CA) and R Software Version 3.3.0. Locations of ORV use were identified by examining user uploaded GPS tracks from personal rides (Offroading Home, 2016). Trails were available for five western states (AZ, CA, CO, NV, and UT), and individual trails from each were downloaded and transformed from Google Earth Keyhole Markup Language (KML) files to shapefiles using the ArcGIS conversion utility. All trails were individually examined while overlaid with satellite images in order to visually verify that travel was completed exclusively on unpaved surfaces. Any trail that included travel on a paved road or highway was subsequently omitted. Trails that were duplicates of others were also omitted.

The locations of known NOA and NOE deposits were identified from multiple sources. The United States Geological Survey (USGS) has previously catalogued the location of known mines and natural occurrences of chrysotile and fibrous amphibole asbestos. This data was downloaded as a shapefile and projected as a map layer in ArcGIS (United States Geological Survey, 2014). Other known locations of NOA not described by USGS were merged into the USGS map layer. These included natural occurrences of fibrous amphiboles in Southern Nevada (Buck et al., 2013; Kleinfelder, 2014; Tetra Tech Inc., 2014) and Arizona (Metcalf and Buck, 2015). Locations of NOE were mapped using data provided in the supplementary material of Van Gosen et al. (2013), which describes the geological features of each occurrence and its corresponding latitude and longitude. The extent of ORV trails in close proximity to NOA and NOE sources was examined by calculating the total length of ORV trails within varying buffer radii (5, 10, 15, 20 miles) of each deposit. Trail lengths per buffer region were calculated using R Version 3.3.1.