Agriculture, Ecosystems and Environment 240 (2017) 101–108

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Research Paper

Particulate capture efficiency of a vegetative environmental buffer surrounding an animal feeding operation

William B. Willis[a,*], William E. Eichinger[a], John H. Prueger[b], Cathleen J. Hapeman[c], Hong Li[d], Michael D. Buser[e], Jerry L. Hatfield[b], John D. Wanjura[f], Gregory A. Holt[f], Alba Torrents[g], Sean J. Plenner[a], Warren Clarida[a], Stephen D. Browne[a], Peter M. Downey[c], Qi Yao[g]

[a] IIHR Hydroscience and Engineering, University of Iowa,300 Riverside Drive, Iowa City, IA, 52242, USA
[b] US Department of Agriculture, Agricultural Research Service (USDA-ARS), National Laboratory for Agriculture and Environment,2150 Pammel Drive, Ames, IA 50011, USA
[c] US Department of Agriculture, Agricultural Research Service (USDA-ARS), Henry A. Wallace Beltsville Agricultural Research Center,10300 Baltimore Avenue, Beltsville, MD 20705, USA
[d] Department of Animal and Food Sciences, University of Delaware, 237 Townsend Hall, Newark, DE 19716, USA
[e] Biosystems & Agricultural Engineering Department, Oklahoma State University, 111 Ag Hall, Stillwater, OK 74078, USA
[f] US Department of Agriculture, Agricultural Research Service (USDA-ARS), Cotton Production and Processing Research, 1604 E FM 1294, Lubbock, TX 79403, USA
[g] Department of Civil and Environmental Engineering, University of Maryland, 1173 Glenn L. Martin Hall, College Park, ML 20742, USA

ARTICLE INFO

Article history:
Received 21 June 2016
Received in revised form 3 February 2017
Accepted 6 February 2017
Available online 24 February 2017

Keywords:
Vegetative environmental buffer
Shelterbelt
Particulate
Lidar
Emissions
Animal feeding operation

ABSTRACT

Particulate matter emitted from tunnel-ventilated animal feeding operations (AFOs) is known to transport malodorous compounds. As a mitigation strategy, vegetative environmental buffers (VEBs) are often installed surrounding AFOs to capture particulates and induce lofting and dispersion. Currently, point measurements are the primary means by which VEB performance has been investigated. The existing techniques lack spatial and temporal resolution and fail to assign the observed particulate reduction to capture, lofting, or dispersion. This study presents a technique for estimating the capture efficiency of a VEB using lidar and attributes all observed reduction to particulate capture, thereby delineating the effects of capture and lofting. The experiments revealed a capture efficiency ranging from 21 to 74%. Instantaneous lidar scans showed periodic lofting well above the VEB, but when scans were averaged over several hours, the plumes appeared Gaussian. This paper documents experimental evidence quantifying the capture efficiency of a VEB. It also establishes an experimental framework for future studies on the efficacy of various emissions mitigation strategies.
© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Over the last few decades, advances in mechanical, biological, and chemical technologies have allowed for single farms to manage larger numbers of animals. As a result, many sectors of animal husbandry have shifted toward large-scale production (MacDonald and McBride, 2009). This approach increases efficiency and reduces cost, but the practice concentrates animals onto smaller plots of land, concentrating animal-derived pollution. Pollution from animal agriculture has become a growing concern. Thus, researchers and policy makers are focusing much attention on the measurement, modeling, control, and management of airborne emissions from agricultural sources (Aneja et al., 2009).

Concentrated animal feeding operations (AFOs) emit particulate matter, ammonia, and several other constituents into the atmosphere in high concentrations, and the pollutants travel downwind while dispersing into neighboring communities, causing numerous community health and socioeconomic problems (Donham et al., 2007). In this study, we focus on the transport of particulate matter from poultry houses and its interaction with a mitigation strategy known as vegetative environmental buffers. While AFOs emit numerous constituents which all have their own unique behavior and environmental impacts, only particulate matter emissions were measured in this study. These

* Corresponding author.
E-mail address: willbranwill@gmail.com (W.B. Willis).

http://dx.doi.org/10.1016/j.agee.2017.02.006
0167-8809/© 2017 Elsevier B.V. All rights reserved.

measurements do, however, reveal the nature of the transport processes for other constituents outside these facilities. The measurement techniques described herein can be directly applied to other constituents in the future.

Particulate matter, which consists of fecal matter, feed particles, and feather and epidermal fragments, is known to cause adverse health effects when inhaled (EPA, 2009). In addition, the particulates emitted from AFOs can transport odorous compounds downwind (Burnett, 1969; Hammond et al., 1979, 1981; Hammond and Smith, 1981; Yang et al., 2014). Odor creates a burden on communities and induces stress; the complaint of odor is common amongst communities residing near AFOs (Wing et al., 2008; NRC, 2003). Odor itself has been shown to cause adverse health effects, including eye, nose, and throat irritation, nausea, cough, shortness of breath, and alterations in mood (Schiffman et al., 2000). A reduction in odor emitted from AFOs can be achieved by reducing particulate matter, since particulate matter is a known odor transport vector. Several post-emission mitigation strategies have been employed to absorb or deflect particulate emissions (Ni, 2015). Vegetative environmental buffers (VEBs) are one technology commonly used.

Vegetative Environmental Buffers (VEBs), also known as shelterbelts, are strategically placed rows of trees and shrubs that help control emissions from agricultural sources to the atmosphere. VEBs are highly regarded for their ability to: (1) enhance vertical mixing in the atmosphere, leading to dispersion and dilution; (2) filter particles mechanically by acting as a porous medium; (3) precipitate particles by reducing wind speed; and (4) improve producer-community relations by providing a visual and noise barrier (Tyndall and Colletti, 2007; USDA NRCS, 2007). In addition, a recent survey in Iowa (Tyndall, 2009), 52% of producers reported currently-using or expressed an interest in using VEBs specifically to mitigate odor. With this growing demand to use VEBs, it is critical that our understanding of the technology outpace its application, so that extension services can be carried out appropriately (Tyndall, 2009). However, our knowledge of VEB efficacy is lacking; a need exists to quantify and document VEB performance, which is difficult due to the complex processes involved in a functioning VEB. Particulate capture efficiency (percent of particulates retained by the VEB) is one measure of VEB efficacy. Capture efficiency measures only the effect of particulate trapping and neglects dispersion, dilution, and psychological effects. In this study, we conducted a field campaign to estimate VEB particulate capture efficiency using lidar.

Estimating the VEB capture efficiency requires that emissions be measured both upwind and downwind of a VEB. Also, the extent of the entire plume needs to be examined. Plumes emitted from animal houses have been shown to exhibit non-Gaussian dispersion and periodic lofting as a result of turbulence fields disrupted by the facilities themselves. In some cases, the plumes reach up to 40 m above the ground surface, well above most sampling towers (Prueger et al., 2008; Holmén et al., 1998). As a result, only a limited number of experiments have been conducted to quantify VEB capture efficiency (Table 1).

Wind tunnel studies (Laird, 1997; Thernelius, 1997) have proven useful for examining the entire plume extent, while field campaigns (Parker et al., 2012; Hernandez et al., 2012; Malone et al., 2006a; Lin et al., 2006) have provided data in a more realistic setting. Past field campaigns have used either point sensors or trained human panelists, but these measurements can only help quantify particulate reduction between the specific locations where they are placed. The observed reduction in particulate count may be the result of the combined effects of dispersion, lofting, and VEB capture. Therefore, experiments using point measurements have not precisely estimated capture efficiency. Parker et al. (2012) recognized this deficiency and concluded that investigation into the differences between the various effects is warranted to understand VEB performance more completely.

Lidar (light detection and ranging) has proven to be an effective remote sensing technique for estimating emission rates from AFOs (Bingham et al., 2009; Lewandowski 2009; Holmén et al., 1998). In the lidar technique, a short pulse (10 ns) of infrared light is emitted into the atmosphere. The pulse interacts with particulates in the air; a fraction of the pulse scatters in all directions; and the portion that scatters back to the lidar is collected in a telescope and focused onto a detector. The backscatter intensity is proportional to the number of particulates present in the sampling volume, and the range is proportional to the pulse travel time. The lidar is stepped through a series of vertical angles to measure a cross-section of a particulate plume. The technique provides high spatial resolution of particulate concentration around the facility while automatically capturing and retaining data with minimal labor involved. For a detailed description of lidar methodology, see Kovalev and Eichinger (2004). In this study, we adapted the lidar technique to estimate VEB particulate capture efficiency. This lidar technique allows for the entire plume to be mapped downwind of the VEB and for the effect of particulate trapping to be delineated from the effects of dispersion and lofting. The alternative method of point sampling can only strictly show the concentration reduction between a single upwind and downwind location. Using this method, the observed reduction may result from the combined effects of particulate trapping, lofting, and dispersion. Thus, the lidar technique provides a more accurate assessment of the particulate capture efficiency of VEBs surrounding animal housing facilities.

2. Methods

2.1. Study site

The study was conducted at the broiler house at the University of Delaware Carvel Research and Education Center (38.64, −75.47) between June 24 and 26, 2013 (Fig. 1). The University of Iowa elastic scanning lidar was positioned 410 m from the site so that it could

Table 1
Summary of efforts to quantify the effectiveness of vegetative environmental buffers at reducing particulate matter quantities and odor levels.

Reference	Reduction in Emissions	Methodology
Parker et al. (2012)	66.3% reduction in odor at 15 m downwind	Trained human panelists
Hernandez et al. (2012)	40% reduction in total PM counts; 40–60% reduction in odorous compound concentration	Optical particle counters; Sorbent tubes
Malone et al. (2006a)	49% reduction in PM concentration	Gravimetric filters
Laird (1997) and Thernelius (1997)	35–56% reduction in PM mass	Open-circuit wind tunnel, using digital imaging to relate brightness to dust deposition
Lin et al. (2006)	68% reduction in odor 117 m downwind	Trained human panelists

Download English Version:

https://daneshyari.com/en/article/5538159

Download Persian Version:

https://daneshyari.com/article/5538159

Daneshyari.com