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Original Research

Analysis of Noxious Gas Pollution in Horse Stable Air

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ABSTRACT

The aim of this study was to determine quantitative and qualitative occurrence of noxious gas compounds in the stable, depending on the time of the day (4:00 AM, 12:00, 8:00 PM), the height (20 cm, 150 cm), and the place (boxes, aisle) from which the samples were collected. Seven compounds were analyzed (NH_3, SO_2, COS, HCN, CH_4, NO_2, and CO). For analyzing stable air, a mobile gas analyzer was used. The time of day was a significant differential factor ($P < .01$) for concentrations of NH_3, COS, and CH_4. The highest concentrations of CH_4, COS, NO_2, NH_3, and CO appeared at 4:00. For the rest of the studied compounds (SO_2, HCN, CO) differences were not statistically significant, but there was a tendency for the highest concentrations at 12:00. The concentrations of gas compounds depending on height did not differ significantly from each other, but there was a tendency for higher concentrations of NH_3, SO_2, CH_4, and CO at 150 cm and for HCN at 20 cm. COS and NO_2 remained constant at both heights in boxes. The places where the samples were collected was a significant differential factor ($P < .01$) for NH_3 and SO_2. For the rest of the studied compounds the differences were not statistically significant. It can be concluded that many noxious compounds may appear without being noticed, and that is why it is necessary to provide stables with efficient air exchange throughout the day.

1. Introduction

The air within many livestock buildings contains many noxious admixtures such as microorganisms (bacteria, viruses, molds, feces, plant material, bacterial endotoxins, β-glucans, inorganic dust particles, and gases) [1-3]. Domestication of horses and their uses in sport and leisure activities are closely linked with housing, especially the use of box stalls. High sport class horses often spend most of their lives (even up to 23 hours per day) in their stalls [4-6]. Therefore, the quality of the surrounding air in horse stables is an important factor in maintaining the good health of horses, because the equine respiratory tract is sensitive inter alia to noxious gases [7]. Among those factors that influence the air quality in the stable, the type of bedding materials [6,8-11], removal of manure [4,7,12], and ventilation system [13] seem to play important roles in creating microclimatic conditions. According to Wheeler [13], the most common mistake made in construction and management of modern horse facilities is failure to provide adequate ventilation.

Appearances of gas compounds in the stable contains a serious risk for both horses and people working in a stable. The gas most commonly identified in stables is ammonia (NH_3), which, in addition to its negative influence on animals' and people's respiratory tract [14-16], may be emitted for long distances through the air, causing eutrophication of water and vegetation [17,18]. Sulfur dioxide (SO_2) belongs to the odor compound group which, in addition to its nuisance odor, has a noxious influence on health and living comfort for both human and animals [15]. Carbon monoxide (CO) is an odorless compound, but it has a serious toxic effect; inhalation of CO at high doses is fatal

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[15]. Hydrogen cyanide (HCN) blocks molecular oxygen transfer in cytochrome oxide system in mitochondria, causing tissue anoxia [15]. Nitrogen dioxide (NO_2) can pass through the upper airway and permanently damage the respiratory tract [15]. The inhalation of high doses of carbonyl sulfide (COS) can cause hyperemia of the tracheal mucosa and peritoneal cavity and pooling of blood in the lungs [19]. Methane (CH_4), one of the main greenhouse gasses, plays an important role in global warming. According to Moss et al. [20], agricultural emissions of methane have recently been estimated at 10.2 million tons per year, and of these, approximately one-third comes from livestock manure.

To develop environmentally sound, sustainable agricultural operations, it is necessary to integrate research that focuses on modern analytical techniques and the latest sensory technology of measurement and evaluation of odor and pollution, together with fundamental knowledge of factors that are the basic units contributing to the production of odor and pollutants [18].

The aim of this study was to quantitatively and qualitatively identify harmful chemical compounds appearing in the air of the stable with typical management depending on time of day, height (20 cm, 150 cm), and place (aisle, boxes) where the samples were collected from.

2. Materials and Methods

2.1. Animals

The procedures involving animals were approved by a local care committee. The horses involved were kept in boxes in consideration of the guidelines of Regulations of the Ministry of Agriculture and Rural Development [21] considering keeping horses according to animal welfare.

2.2. Experimental Setup

The study was conducted during 7 consecutive days in the November–December period, as the autumn-winter season, especially in a temperate climate such as Poland's, is the season when horses spend more time in the stable and the natural ventilation at that time is often poor, resulting from closed gates in stables, which effects greater concentrations of noxious pollutants in the air. The box stable was located in the tourist region of Poland. During the investigation, a gas composition analysis of air was performed. The analyzed chemical compounds were CH_4, COS, NO_2, CO, HCN, SO_2, and NH_3. The thermal-humidity conditions and the air flow rate in the stable were also investigated.

2.2.1. Stable Characteristics

Figure 1 shows the plan of the stable. The longitudinal length of the stable was 52 m, the width was 11 m, the height was 4 m; a utility room (72 m^2) was separated from the rest of the stable by a wall and therefore was not taken into account when we calculated the stable volume (2000 m^3) and cubic capacity (143 m^3) of the stable. The usable area of the stable measured 500 m^2 and had 14 boxes and the washer, together with a grooming place to clean the animals. Along the stable in its center ran a corridor (52 m × 3 m). Boxes were situated in parallel along both sides of the building and differed in size: six boxes had dimensions of 4 m × 4 m, while the eight remaining boxes were 4 m × 3 m. A two-leaf door was placed in both central walls of the stable. Stable doors were closed completely from 10:00 PM to 8:00 AM, while during the day, one leaf of the door remained open. The stable featured mechanical ventilation which was not turned on during the investigation period, and the fresh air in the stable was provided through an open door at both ends of the building, and its exchange during the day took place in an uncontrolled manner. Boxes were separated by walls, where 1.2 m was constructed of solid planks, above which was a grill with a height of 1 m; in each box, there was one horse. Oat straw was used as bedding material (1 kg/m^2). Three times a day, the manure pit and humid straw were removed from boxes, and every 4 days a complete replacement of litter was performed. During the study, there was no interference in the behavior of the animals' owners, and during their work in the stable, opening and closing the doors and heating the utility rooms were left to their choice.

2.2.2. Animals

All 14 horses kept in the stable were Warmblood breeds and were used in sport or recreation. All horses were adult animals and were over 4 years old. Eight horses went outside from 9:00 AM to 3:00 PM, whereas the remaining horses left the stable only for training for 1-2 hours in the evening.

2.3. Measurement and Analysis Techniques

2.3.1. Gas Concentration

For analyzing the air gas pollution, a Fourier transform infrared (FTIR) mobile gas analyzer (DX-4030 model Gasmet) was used. IR spectroscopy is a technique for chemical analysis and determination of molecular structure in solid, liquid, and gaseous states. The principles that molecular vibrations occur in the infrared region of the electromagnetic spectrum and functional groups in chemical compounds have characteristic absorption frequencies are the bases of this technique. The DX-4030 model analyzer was designed for on-site measurements of various organic and inorganic compounds at low concentrations in ambient air. Gasmet analyzer incorporate a FTIR spectrometer, a high-sensitivity sample cell for lowest possible detection limits, and signal processing electronics. The collection of single sample from one measuring point required 5 seconds. To avoid measurement error resulting from the presence of air in the sample cell from the previous measuring point, five samples of air were collected from every measuring point, and every fourth sample was used for the evaluation.

2.3.2. Temperature and Humidity

Measurements of air temperature and humidity were carried out using electronic thermo-hygrometers (LB-520), which registered the above-mentioned microclimate factors in 2-hour intervals on a continuous basis throughout the study. Seven recorders were located at fixed sites inside