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Research Paper

Assessing fresh urine puddle chemistry in commercial dairy cow houses

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Ammonia emission mainly originates from urea in urine puddles on floors in dairy cow houses. This emission process can be modelled. However, required model inputs have not been updated recently. In addition, values for the model variables *pH*, Urinary Urea Nitrogen concentration (*UUN*), and their relation with farm and feed management are unknown for commercial dairy cow houses. Moreover, their effect on ammonia emission is unknown. Therefore, the objective of this paper was to investigate the *pH* and *UUN* in livestock practice. Sixteen commercial farms were measured in a factorial design of four Floor-Management types (*FMTypes*). Each farm was measured in two seasons and a *Diet* factor was defined, based on the amount of grass in total roughage. Overall mean values were 4.27 kg m^{-3} for *UUN*, an initial *pH* of 8.3, both in fresh puddles, and a $pH(\xi)$ of 9.0 for random puddles at a random time. For *UUN* both the variation within and between farms was large, whereas the variation for *pH* was small. The *Diet* was the only factor that resulted in a significant effect, with a 0.1 difference in $pH(\xi)$. Compared to the reference values, both the mean *UUN* and *pH* showed smaller values. The calculated potential ammonia in kg $puddle^{-1}$, however, showed a huge range and was considerably larger than the commonly used reference values in the Netherlands.

1. Introduction

Ammonia (NH_3) emission strongly contributes to the acidification of the environment. In the Netherlands, the NH_3 emission from dairy cow houses is one of the largest sources (Velthof et al., 2012), and reductions are needed to comply to EU National Emission Ceilings (NEC) (EU, 2001). NH_3 emission originates from urea in the urine on top of the floor (70%) and from urea in the slurry in the pit beneath the floor (30%) Monteny, Schulte, Elzing, and Lamaker (1998).

NH_3 emission from dairy cow houses can be reduced by feed measures to minimize urea excretion, as well as measures that aim to improve manure scraping management and floor design. In the process of developing and optimizing mitigation measures, NH_3 emission models that describe the underlying processes and involved key variables in the emitting surfaces are a very useful and powerful tool (Elzing &

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Nomenclature

NH_3	ammonia [various]
pH	urine puddle pH [–]
UUN	urinary urea nitrogen CONC [kg m^{-3}]
MUN	milk urea nitrogen CONC [mg/100 g milk]
T_{liq}	urine puddle temperature [°C]
T_{air}	air temperature ± 1 m above puddle [°C]
RH	air humidity ±1 m above puddle [%]
A_p	urine puddle surface area [m^2]
D_p	urine puddle depth [mm]
NH_3S	NH_3 source size of a puddle [kg]
(0)	fresh urine puddle at $t = 0$ s
(ξ)	random urine puddle at $t = \xi$ s
FMType	floor-management type
SFR	slatted floor reference
GF	grooved floor
AF	V-shaped asphalt floor
SFCO	slatted floor at C & O farms
C & O	cows & opportunities, mineral management project
Season	two seasons
W	winter
S	spring
PREclean	intense-floor-cleaning before puddle creation
Diet	grass content of total roughage
G	grass >66.67% of total roughage
GM	grass <66.67% of total roughage

Monteny, 1997). More details on available models, their use and current limitations can be found in Montes, Rotz, and Chaoui (2009) and Snoek, Stigter, Ogink, and Groot Koerkamp (2014). One of the major limitations is the little information about the values of the key variables like the puddle surface, pH and urea concentration under practical conditions (Snoek et al., 2014). Without accurate data, it is not possible to develop a NH_3 emission model that is capable of accurate assessments of the impact of new mitigation measures, and providing support to the innovation of floor designs and manure scraping measures.

Effects of floor design and management on the key variables urine puddle depth and puddle area in commercial dairy cow houses were shown in Snoek, Stigter, Blaauw, Groot Koerkamp, and Ogink (2016c). Feed management, and the local climate result in varying chemical characteristics of the urine, for example, different pH and urinary urea nitrogen concentration (*UUN*) values (Monteny, Smits, van Duinkerken, Mollenhorst, & de Boer, 2002; van Duinkerken, Smits, André, Šebek, & Dijkstra, 2011) and varying puddle and air temperature and air humidity. The milk urea nitrogen concentration (*MUN*) also varies, as a result of different feed management. Several authors have demonstrated positive relationships between *MUN* and *UUN* (Burgos, Fadel, & DePeters, 2007; van Duinkerken et al., 2011). In commercial dairy cow houses, however, Burgos, Robinson, Fadel, and DePeters (2005) did not find correlations between *MUN* and *UUN*. That said, it is expected that NH_3 emission can be lowered by adjusting the feed management. Besides, recently a tool to visualise the effect of farm management on a farm's nutrient cycle was introduced. The Annual Nutrient Cycling Assessment (ANCA) is a license to produce for dairy farms with a manure surplus from 2015 onwards (Aarts et al., 2015, pp. 377–379). But to the best of our knowledge, the *pH* and *UUN* values and the extent of the effects by farm & feed management and climate on them are unknown for commercial dairy cow houses.

So, to provide information on these key variables that represent practical dairy cow house conditions, we carried out a field study in which fresh dairy cow urine puddles were measured in a variety of cow house designs based on the floor type in the cow walking area. Use was made of new methods developed for measuring puddle characteristics under practical barn conditions (Snoek, Stigter, Ogink, & Groot Koerkamp, 2015, 2016a,b).

In the accompanying paper of Snoek et al. (2016c), we focused on the physical characteristics of a urine puddle and relationships with floor design and scraping management. In the current paper, we focus on the chemical characteristics of a urine puddle and the local climate: the *pH* and urea concentration, plus temperature, and some aerial conditions. The objective of the current paper is 1) to assess the Urinary and Milk Urea Nitrogen concentration (*UUN*, *MUN*), the related potential NH_3 source size, the initial *pH* (*pH*(0)), the *pH* at a random moment (*pH*(ξ)), the puddle and air temperature (T_{liq}, T_{air}), their variability and the relations between them in commercial dairy cow houses, and 2) assess the effect of floor type, season and feed management on these variables. Implications for model improvements and current measurement practices (Ogink, Mosquera, & Hol, 2013) will be identified.

2. Materials and methods

2.1. Experimental design

The experimental design is described in more detail in Snoek et al. (2016c).

2.1.1. Design and experimental factors

In total, we measured urine puddle characteristics at 16 commercial dairy farms, spread over The Netherlands. These farms were divided into a factorial setup over four Floor-Management types (*FMTypes*). Each *FMType* consisted of four farms. The *FMTypes* were (1) slatted floor farms representative for the reference cow house type (*SFR*), (2) completely closed grooved floor farms (*GF*), (3) completely closed V-shaped asphalt floor farms (*AF*), and (4) slatted floor farms that participated in the Cows & Opportunities project (*SFCO*). Cows & Opportunities farmers actively manage the nutrient cycle of the cows to lower NH_3 emission (Aarts et al., 2015, pp. 377–379; Oenema, Koskamp, & Galama, 2001). The two pre-set experimental factors were *Season*, which represented the measurements in winter (*W*) and spring (*S*), and *PREclean*, which represented the simulated intensively-cleaned-floor-effect before puddle creation on the D_p measurements as compared to on-farm manure scraping if present (Snoek et al., 2016c). Each farm was measured in both *Seasons*, and *PREclean* was applied at each farm. Additionally, there were two