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Research Paper

Assessing fresh urine puddle physics in commercial dairy cow houses

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Ammonia emission from dairy barns can be reduced by measures that improve removal of urine from floors. Information characterizing physical and chemical properties of urine puddles on floors are essential to improve mitigation measures, however information representative for practical barn conditions is scanty. The objective of this paper is to assess the area (A_p) and depth (D_p) of fresh urine puddles in commercial dairy barns, and to investigate the effect of floor type, season and manure scraping on these variables. Sixteen farms were measured in a factorial design of four Floor-Management types (*FMTypes*). Each farm was measured in two seasons and underwent an intense-floor-cleaning treatment (*PREclean*) before puddle creation for the D_p measurement, which was compared with those created under normal floor conditions with on-farm manure scraping. Overall mean values were 0.83 m^2 for A_p and 1.0 mm for D_p. For both A_p and D_p the variation within a farm was large but negligible between farms. *FMType* significantly affected both variables. The V-shaped asphalt floor resulted in larger A_p (1.04 m^2) and D_p (1.5 mm) than those of slatted and grooved floors (mean values 0.76 m^2, 0.93 mm). Our study demonstrates that the draining capacity of solid floors is a critical design issue in lowering ammonia emission. The *PREclean* treatment resulted in D_p values that were 3 times lower than values for puddles created under normal floor conditions. We conclude that there is a considerable potential to improve draining of excreted puddles by increasing the cleaning performance of manure scrapers.

1. Introduction

Ammonia (NH_3) emission strongly contributes to the acidification and eutrophication of the environment. To restrict NH_3 emission, the EU has set National Emission Ceilings (NEC) (EU, 2001) that, in the last 25 years, have substantially decreased NH_3 emission in the EU (EEA, 2012). Nevertheless, the latest (2012) reported total NH_3 emission in for example the

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Nomenclature

NH^3	ammonia [various]
pH	urine puddle pH [–]
UUN	urinary urea nitrogen CONC [kg m^{-3}]
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]
(0)	fresh urine puddle at $t = 0$ s
(ξ)	random urine puddle at $t = \xi$ s
Tac-Rav	technical advisory committee for NH_3 regulation
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

Netherlands (136 kt) is still above the current NEC (128 kt) (EEA, 2015). In general, NH_3 emission in the EU is dominated by agriculture, which accounts for almost 95% of the total emissions in the EU-27 (EEA, 2015). Within agriculture, dairy cow houses represent a substantial source of NH_3 emission and their contribution in for example the Netherlands is estimated to be about 13% (Velthof et al., 2012). In a cow house, NH_3 emission originates from urine puddles on the floor and, where present from slurry in the manure storage below the floor.

NH_3 emission from dairy cow houses can be reduced by feed measures to minimise urea excretion, as well as measures that aim to improve manure scraping management and floor design. New types of floors are one of the main approved and applied NH_3 emission reduction methods in the Netherlands, together with the use of a manure scraper (Tac-Rav, 2016). Both floor design and a manure scraper affect the physical characteristics of urine puddles and faeces heaps on the floor, and thus affect NH_3 emission (Braam, Ketelaars, & Smits, 1997, Braam, Smits, Gunnink, & Swierstra, 1997; Poteko, Schrade, Steiner, & Zähner, 2014). In the process of developing and optimizing such 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. They provide insight in how proposed mitigation measures may affect the emission process, how they can be improved and what impact on emission can be expected. Such models can also be used to perform pre-assessments of the mitigation capacity of new cow floor designs that are developed by industry. For example, in the Netherlands such pre-assessments are carried out for regulatory purposes by making use of the model developed by Monteny, Schulte, Elzing, and Lamaker (1998). Besides the model elaborated by Monteny et al. (1998) a variety of emission models have been developed that aim to describe NH_3 emission processes (Montes, Rotz, & Chaoui, 2009; Muck & Steenhuis, 1981; Vaddella, Ndegwa, & Jiang, 2011, 2013). To make optimal use of emission models in the development of mitigation measures it is crucial that input values of key variables, like puddle surface area, pH, and urea concentration in urine, are representative for practical conditions in a cow house. However, little information is known about these practical conditions, and as such, it is difficult to accurately estimate input values that reflect floor and management characteristics of new housing designs. This scarcity of information is mainly caused by the complexity of measuring required floor and manure storage variables under real cow house conditions. The little information we have on the model variables is mostly based on research done before 2000 under cow house and management conditions that may have changed since then. Furthermore, most information related to floor characteristics has only been measured under laboratory conditions (Braam, Ketelaars, et al., 1997) and it is not sure how close obtained values approach practical values. Therefore, to make efficient use of models in developing mitigation measures there is a need for actual measurement data of these input variables from dairy cow houses reflecting current practical conditions.

Current emission models include a wide range of variables that vary in terms of impact on the emission. When setting up research to derive input values of variables under practical conditions, it makes sense to focus on the variables that have the highest impact on emission. To identify the most important variables in the process of emissions from floor puddles, various NH_3 emission models were tested in a sensitivity analysis (Snoek, Stigter, Ogink, & Groot Koerkamp, 2014). The analysis showed that five puddle-related input variables: pH, depth, area, urea concentration, and temperature, were the most important ones to explain variation in NH_3 emission from puddles on the floor. These findings hold true regardless of the actual model parameters. The remaining four variables were the air temperature and air velocity just above a puddle, the maximum rate of urea conversion or urease activity, and the Michaelis–Menten constant. The study of Snoek et al. (2014) also concluded that hardly any measurement data is available on these variables from urine puddles in commercial dairy cow houses. In other words, values, distributions, and correlations of the variables are unknown. 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.

To provide information on 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 cow house conditions (Snoek, Stigter, Ogink, & Groot Koerkamp, 2015; Snoek, Hofstee, et al., 2017; Snoek, Ogink, et al., 2016). In this paper, we focused on the physical characteristics of a