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A laboratory study of the effect of coating on cleanability of concrete flooring for use in piggeries

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The objective of the study was to examine the effects of five plastic coatings on cleanability of concrete flooring. In the laboratory it is easier to use simplified model soils (dirts) than actual soils present in piggeries. The aim of the study was particularly to examine the correspondence between the cleanability of the surfaces using simple model soils in a radiochemical reference method and manure soil in a colorimetric study. According to both colorimetric and radiochemical measurements, coating of concrete improved the cleanability of the flooring. The use of coating can thus be justified in sites in which a high cleanness level is required, probably meaning that coatings will be used only in some sites in animal production buildings. According to the colorimetric results, coating also decreases the time required for cleaning. As an important result for further studies concerning comparison of surface materials for animal buildings, this study demonstrated that cleanability of the surfaces from manure soil could be described by both ^{14}C- and ^{51}Cr- labelled radiochemical model soils (correlation coefficients 0.656 and 0.691, respectively). The quantitative radiochemical method is an excellent way to detect soil absorbed in materials. This is important especially from the point of view of durability, because soil absorbed in the flooring material causes chemical attack, which weakens the material in the long run.

1. Introduction

Agricultural environments are challenging from the point of view of durability and cleanability of materials. Several substances wear, weaken and soil the floorings. These include for example mixtures of manure, feed and washing waters with chemical load. Choice of materials in piggeries is an important factor affecting the well-being of animals by allowing the species-characteristic behaviour of the animals and preventing injuries and diseases (Baxter, 1984; Hoy *et al.*, 1999). In addition, the material chosen also affects the comfort and safety of the personnel working in animal production buildings. When the aim is to produce safe food products, requirements for hygienic properties for the production plants are also of importance (McClanahan, 2005). Furthermore, the hygienic environment of the

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Nomenclature

L^*	whiteness value (1 = black, 100 = white)
a^*	red/green chromaticity coordinate
b^*	blue/yellow chromaticity coordinate
ΔE	total change in colour, %
N	number of samples
p	probability
r	Pearson's correlation coefficient
V	volume

Subscripts

s	soiled
c	cleaned

animals affects the organoleptic quality of meat (Maw *et al.*, 2001).

Concrete is the most common material for solid and slatted floors of piggeries (De Belie, 1997). Concrete is not resistant to acids (De Belie *et al.*, 1996). The dominating source of acetic acid, a weak acid, is manure (De Belie *et al.*, 1996). Manure acidifies over time. Regular and efficient removal of manure when fresh thus helps prevent concrete from weakening (Mathiasson *et al.*, 1991). Lactic acid, also a weak acid, is formed by feed residues (De Belie *et al.*, 1996, 2000a, 2000b). Similarly to acetic acid, lactic acid also weakens concrete slowly (standard ACI 515.1R, 1985). In a study by De Belie (1997), the feeding method of pigs had the greatest impact on erosion of floorings, the most severe damage being in the liquid-feeding site. In addition to acetic and lactic acids, the soil on the floorings of animal sheds contains other compounds such as propionic and butyric acids (Mathiasson *et al.*, 1991; De Belie *et al.*, 1996), valerian and capronic acids (Mathiasson *et al.*, 1991) and aggressive ions NH_4^+, Mg^{2+}, Cl^- and SO_4^{2-} (De Belie *et al.*, 1996). There are considerable amounts of chlorides and sulphides in liquid manure (Calleja Carrete, 2005).

Both chemical substances and mechanical impact on floorings cause corrosion and wear that may promote injuries to the animals. In addition, it may make cleaning difficult, thus promoting spread of diseases (De Belie, 1997; De Belie *et al.*, 2000b). Therefore the use of coatings to protect the surface of concrete against wear is of interest. For example, polyurethane has sometimes been used in cow houses and horse stalls, but its use in animal floorings is not widespread. There are only a few previous studies concerning the cleanability of materials in animal houses (Sundahl, 1974; Hörndahl, 1995; Puumala & Lehtiniemi, 1993; Larsson, 2000; Zhang *et al.*, 2006). In some of these studies, visual and qualitative evaluation methods were mainly used. In the study by Larsson (2000), a protein test and microbiological contact slides were also tested for evaluating the effect of cleaning in pig pens. In a study by Pelletier *et al.* (2002), the effect of cleaning was evaluated by a microbiological assay using plate count agar. In a study by Zhang *et al.* (2006), the cleaning result was assessed optically in the visible and near-infrared optical range.

The aim of the present study was to examine the effects of different coatings on the cleanability of concrete flooring. Colorimetry was used for assessing cleanability of the surfaces from manure soil and paste model soil. A radiochemical method with two simplified model soils was used as a reference method for evaluating cleanability.

2. Materials and methods

2.1. Surface materials

Concrete and five materials containing plastics were examined (Table 1, Fig. 1). Epoxy and polyurethane are plastics that can withstand relatively high temperatures and they are widely used for improving the cleanability of the surfaces in animal production buildings. Epoxy-based coatings belong to the most commonly used coatings in agriculture. Polyurethane is somewhat elastic, and with this plastic it is possible to repair small cracks in concrete floors. These cracks appear in older floors due to slight movement of the ground construction. All the coatings examined were commercial products, commonly used for example as floorings in industrial buildings. Rubber was selected for the experiments because it was considered that as a relatively smooth material it might smooth the whole coating. Rubber as an additive can be used with polyurethane because of its elastic characteristics. In this study, the rubber used was an experimental material that is not commercially available for animal buildings combined with polyurethane.

All coatings were spread on ready-made garden concrete tiles (size 500 mm by 500 mm by 50 mm). The coatings of 1–4 mm thickness were prepared by a contractor specialised in fixing plastic coatings. The garden tiles consisted of two layers of concrete. The thickness of the bottom layer was 33 mm and it consisted of 360 kg m^{-3} cement, 70 kg m^{-3} fly ash, 1700 kg m^{-3} gravel (0–8 mm), 200 kg m^{-3} rubble (6–12 mm) and 50–70 kg m^{-3} water. The surface layer was 17 mm thick and it consisted of 400 kg m^{-3} cement, 2300 kg m^{-3} gravel (0–4 mm) and 190 kg m^{-3} water.

The uncoated concrete tiles (size 400 mm by 400 mm by 50 mm) used as reference were cast by the Laboratory of Building Materials Technology at the Helsinki University of Technology. The concrete used (class K30-28, referring to the designed compressive strength of the mixture at the age of 28 days) was fast setting and specially designed for floors. Surfaces of the concrete tiles were finished by troweling 5 h after casting. According to our previous studies (Puumala & Lehtiniemi, 1993; Puumala, 1997) coatings more than 3-mm thick are likely to withstand the acid environment and mechanical stress present in piggeries for more than 10 years, which is the minimum period for reconstruction. In the colorimetric and radiochemical cleanability studies, five replicate samples were examined in all treatments. In the