SELECTED PROPERTIES OF LIGHT REFLECTED BY PHOTOCATALYTIC ACTIVE SURFACE

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Abstract

The paper deals with a change in the luminous radiation reflected by surfaces with coats with photocatalytic active particles. In the executed laboratory experiments, we used two commercially available coats with photocatalysts on the basis of TiO_2 and one coat without photocatalytic active particles. As the luminous radiation source, we used two different light sources with different spectre. The used light sources provided same radiation intensity at the place of measuring of the reflection from the surface of the sample. In individual phases of the experiments, we repeatedly measured the values of impacting and reflected radiation depending on the type of the coat, its moisture and the used luminous radiation source. The coats were applied to the area of 10x10 cm according to the recommendation of the manufacturer. The weight of the coat on thus prepared samples was ascertained by weighing the sample after it dries out. With regard to the elimination of various inhomogeneities in the coat layer on the sample surface, each sample was repeatedly measured both for impacting and reflected radiation (always after having been turned by 90°). The relation between the moisture of the coat and the reflected light radiation was non-linear and the value of reflected radiation decreased with increasing moisture of the coat layer. With increasing moisture of the coat, we also observed shift in the spectre of reflected radiation towards longer wavelengths.

Keywords: TiO_2, coating, moisture, radiation reflection

1. INTRODUCTION

Barns lighting affects not only the wellbeing of the housed animals, but, for instance, also the intake of feed, production and reproduction [1, 2]. Illumination of barns is not only about the sources of this light (natural light, artificial light), but also about the environment where it spreads. In these facilities, we usually deal with multiple reflections of light radiation, and therefore it is important to know the properties of the surface of walls and other areas. In the remodeled bricked barns, walls and ceiling are regularly whitewashed in particular for disinfection. For this purpose, usually calcium hydroxide ($Ca(OH)_2$) and water-based sprayings are used. In the buildings for pig breeding, also were tested coatings with photocatalytic particles of TiO_2 to improve microclimatic conditions by decreasing concentration of the ammonia and greenhouse gases in the air [3, 4, 5]. The side effect of using all these coatings is also the improvement of reflection from the surfaces with the coatings.

The objective of this paper is to ascertain, under laboratory conditions, dependence of reflection of the light radiation from the surfaces with the coatings depending on the moisture of these surfaces. The air humidity in barns is unstable and depends in particular on the season and current atmospheric conditions. In turn, air humidity influences the moisture of walls. During the summer season, in barns with natural ventilation, the caretakers often try to improve microclimatic parameters by ventilators, often even combined with spraying or misting. These measures also affect the course of air humidity in the building. As coatings, we selected the above-mentioned materials, i.e. the mixture of lime and water and three commercially available materials, two with TiO_2. As light sources, we used classic linear fluorescent lights and LED lights. Linear fluorescent lights are still the most frequently used artificial light sources in barns. Recently, however, also LED lights are used in particular due to operational costs savings, and therefore they were selected as second type of artificial radiation source. We also monitored distribution of energy of the reflected radiation into individual wavebands depending on the moisture of the coating and kind of the radiation source. With regard to the volume of measured data and relatively small differences in the measured values, we only present selected results for illustration. For one material we monitored how are the measured values affected by the use of material after its expiration date. In laboratory experiments, we used the findings described by Minton [6].

2. MATERIAL AND METHODS

All experiments were performed under laboratory conditions. In these experiments, we used three commercially available coating materials (hereinafter referred to as material A - D) and one coating material acquired at a farming facility during whitewashing of stables (material E). Material A and B was silicate, water-thinned coating material with photocatalytic active TiO_2-based substance. The difference between material A and B was only in its lifecycle (refer to **Table 1**). Material C was a mild water-thinned water suspension including inorganic binding agents and TiO_2 without treated surface. Material D was water-thinned water suspension of particularly titanium white, kaolines, finely ground limestones, organic dispersion and chemical additives. Material E was prepared by mixing calcium hydroxide and water. All stated materials A - E have been stored, since their procurement, at laboratory temperature.

Table 1 Basic data concerning used coating materials

Coating material	Manufacturing date	Expiration date	Density after dilution	Color of coating material
A	10.06.2016	10.06.2017	1.22 $g.cm^3$	white
B	20.10.2012	20.10.2014	1.21 $g.cm^3$	white
C	30.04.2015	30.04.2017	1.04 $g.cm^3$	transparent
D	27.11.2015	27.11.2017	1.41 $g.cm^3$	white
E	2016		1.25 $g.cm^3$	white

The density of materials A - D was, prior to the experiments, adjusted so that they could be applied to 10x10cm ceramic plates by spraying. The volume and moisture of the applied material was ascertained gravimetrically. Each material A - E was sprayed on five plates. For all material samples, we measured the light radiation reflection from the surface four times for each plate by spectrometer (always after the plate was turned by 90°). For one sample of the tested materials A - E, there was the total of twenty measured values of light radiation reflection from which, medium value was calculated. Various moisture values of the materials on the plate were achieved by drying the plates in the drier at the temperature 35°C. The considered interval of moisture was from 30 to 80%.

In the beginning of the measuring chain, integration cube was used as the light radiation sensor. Distribution of the energy radiated from the reflected light radiation into individual wavebands was also measured. The stated values are geometrical means from measuring that was repeated five or six times.

To measure the light radiation reflection depending on the moisture of the surface of the tested material, three different light sources were used.

Z1: linear fluorescent lights + LED chips

Z2: linear fluorescent lights

Z3: LED chips

Linear fluorescent lights and LED chips (as independent sources) provided comparable lighting. The difference was less than 10%. **Figure 1** shows the courses of spectra of the reflected radiation of all three sources. **Figure 1** also shows two dominant wavelengths of the spectra, where linear fluorescent lights are used (Z1 and Z2). Irregular fluctuations of the lighting caused by sunlight were excluded by blacking out the laboratory windows. We monitored the courses of radiation reflection from the surface of the tested materials depending on the moisture of the surface and calculated the reflection coefficients for **Figure 2**. Materials A - C and sources Z1 - Z3 were monitored for the value of reflected light radiation energy into individual spectrum wavebands (**Table 2**). Here, we also monitored the effect of surface moisture of the tested materials on the volume of light radiation reflection. It can be expected that the photocatalytic process for which materials A - C are used grows slower in time and therefore predominantly the optic function of walls with these coatings persists. From the known density of the tested material, the surface of the plate and weight of the material sample sprayed on the plate, the thickness of the layer of the material on the plate can be, with limited accuracy, determined for the given moisture (even with different moisture). All the measured data were analyzed using the Statistica 10 software.

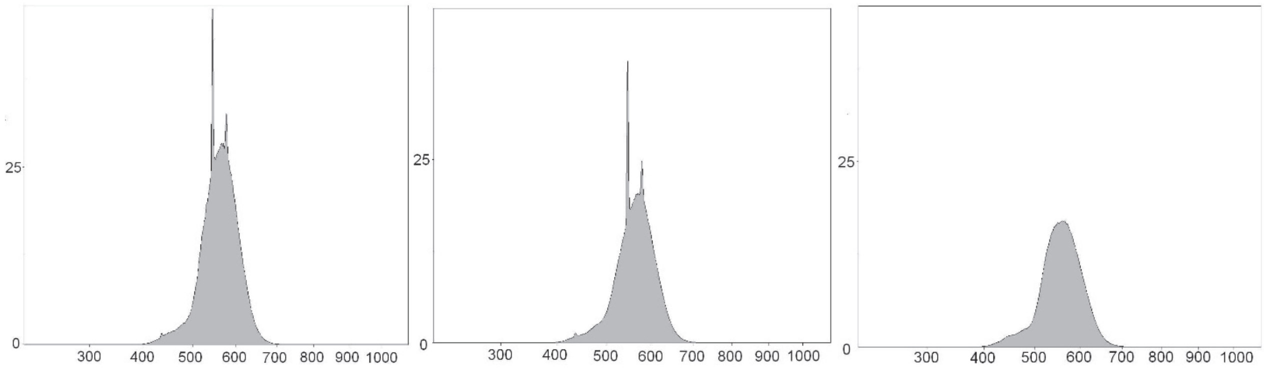

Figure 1 The courses of spectra of the reflected radiation of radiation source Z1 (in the left), Z2 (in the middle) and Z3 (in the right). Horizontal axis - wavelength (nm), vertical axis - luminous flux (lm)

3. RESULTS AND DISCUSSION

All laboratory measuring results were statistically processed and are comprehensively displayed in particular on **Figure 2** and in **Table 2**. The medium value of radiation reflection was calculated as an arithmetical mean of the measured values (**Figure 2**), even though smaller-size sets were processed [7]. The values of energy distribution into individual wavebands depending on moisture are arithmetical means. Even though smaller sets of data were processed, we also used methods described by Dampir et al. [8]. The differences between the used methods were small, therefore we selected the geometric mean as the medium value, in particular with regard to the asymmetrical interval of reliability of the calculated average.

Figure 2 shows, among other things, that age (expired lifecycle) of the tested material (material B compared to material A, refer to **Table 1**) manifests in particular in the lower value of the radiation reflection (for all used light sources). That could be caused by different mechanical composition of material B compared to material A. The surface of the fresh material A in the container was not covered in a layer of liquid as in the case of container with material B. The liquid layer was a few centimetres thick on the surface and the material under this layer was not compact and hard to mix. The composition of this liquid was not monitored. The usual basic components of these coating materials comprise kaoline particles grounded to very small (micrometer) sizes. Other particles with smaller sizes can be progressively pushed out from the mixture along with water upwards creating a liquid layer over the surface of the material in the storage container. This layer may also include TiO_2. This could partially explain also the change in reflection properties of the coatings in time, because TiO_2 is added to the coatings as the white and has better reflection properties than kaoline. However, as **Figure 2** clearly shows, the course of radiation reflection depending on the moisture of the surface of the tested materials is similar for all light sources. A significant difference is obvious in the reflected radiation values for surfaces of various moisture and various light sources.

The trend of the course of radiation reflection depending on surface moisture of material D is similar to material A. However, with decreasing surface moisture, radiation decreases significantly and this decrease occurs with moisture around 60-70%. This decrease occurs with all radiation sources Z1 - Z3.

A somewhat different course of radiation reflection depending on the moisture of the surface was ascertained for material C. This material has a different original composition compared to materials A and B. The maximum of radiation reflection occurs between 50% and 60% of moisture for sources Z1 and Z2 (in both sources, there are active linear fluorescent lights with significant wavelengths) and for source Z3, this maximum is somewhat shifted. On the treated surface, material C creates a very thin transparent layer with TiO_2 particles activated by the UV radiation of the light sources.

With regard to the fact that for barn wall coatings, calcium hydroxide and water mixture is still used most often, we also tested this material for reflection (in **Table 1**, material E). As displayed by **Figure 2**, it mostly reflects radiation less, in particular with higher moisture, than the other materials.

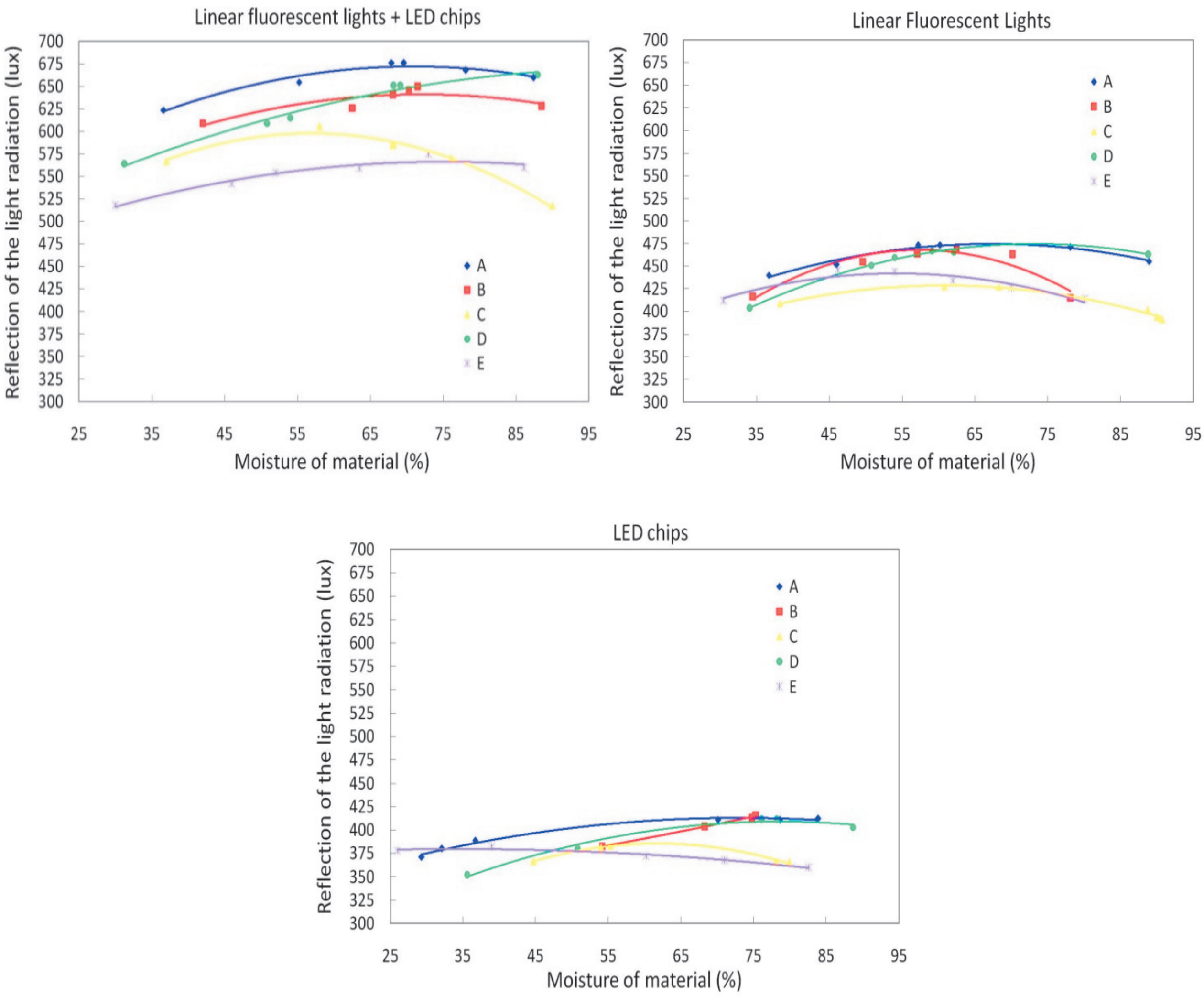

Figure 2 Radiation reflection from the surface of the tested materials depending on the moisture of the surface and on source of light radiation

It must be mentioned that in the barns, we deal almost exclusively with diffusion reflection of light radiation impacting on the material surface which is often very uneven. The sub-layer of the wall coatings and its sorption properties depend on the construction material of the walls. These facts make the prediction of the value of illumination of the premises and of the photocatalytic effects of the coating more difficult. **Table 2** shows that regardless of the type of the light radiation source, with the highest moisture values of the tested materials (as well as with the lowest ones), the reflected radiation achieved lower values. This fact is probably linked to the depth of radiation penetration of the material when reflected from the surface where moisture is one of the variables. The depth of radiation penetration can be counted in microns [9].

Table 2 Distribution of energy of the reflected radiation (W.m^2) into individual wavebands (nm) depending on the moisture of the coating (%) and kind of radiation source - illustration

Sample	Material moisture (%)	400 - 500 nm	500 - 600 nm	600 - 700 nm	700 - 800 nm	800 - 900 nm	900 -1100 nm	Σ
A-1	**23.7**	0.782	0.801	0.714	0.642	1.079	18.56	**23.42**
A-2	**36.6**	0.804	0.840	0.732	0.672	1.104	18.90	**23.92**
A-3	**37.5**	0.849	0.879	0.777	0.729	1.196	20.45	**24.94**
A-4	**44.6**	0.861	0.882	0.778	0.728	1.200	20.44	**24.92**
A-5	**78.0**	0.807	0.859	0.744	0.662	1.084	18.51	**22.60**
A-6	**90.3**	0.818	0.879	0.756	0.651	1.048	18.37	**22.05**
B-1	**36.3**	0.749	0.806	0.712	0.684	1.035	18.09	**22.37**
B-2	**52.5**	0.798	0.845	0.739	0.661	1.087	18.41	**22.60**
B-3	**68.5**	0.781	0.845	0.736	0.671	1.102	18.81	**22.97**
B-4	**78.2**	0.865	0.891	0.782	0.727	1.198	20.41	**24.87**
B-5	**84.1**	0.863	0.886	0.781	0.727	1.195	20.48	**24.92**
B-6	**92.2**	0.898	0.897	0.800	0.769	1.247	21.83	**25.20**
C-1	**28.5**	0.840	0.763	0.714	0.750	1.268	21.86	**26.22**
C-2	**42.7**	0.828	0.756	0.710	0.751	1.272	21.93	**25.31**
C-3	**70.7**	0.752	0.715	0.732	0.672	1.104	18.96	**22.79**
C-4	**78.6**	0.723	0.691	0.642	0.643	1.073	18.33	**22.14**
C-5	**90.3**	0.667	0.524	0.578	0.680	1.158	19.84	**23.50**
C-6	**93.4**	0.665	0.532	0.574	0.684	1.161	19.91	**23.54**

4. CONCLUSION

With regard to the performed laboratory experiments and their results, the following can be observed:

- The spectrum of the used radiation source influences the value of reflection of such radiation from the coating surface.
- The moisture of the coating surfaces affects the volume of reflected radiation. With decreasing moisture of the coating surface, the value of reflected radiation decreases, too.
- Material E consisting predominantly from calcium hydroxide and water shows higher light absorption (smaller reflection) compared to other tested materials.
- The age of the used coating material (with expired lifecycle) affects the volume of reflected radiation. The longer the time from the expiration date, the lower the volume of radiation reflected from the surface regardless of the used light source.
- In periods with high air humidity when also higher moisture of the walls surface in the barns (i.e. humidity will condense on the cold surface of facility walls due to bigger differences between the outdoor and indoor temperatures and insufficient ventilation of the facility) is more likely, light radiation can be expected to be absorbed more by the walls surface.

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