COATINGS WITH PHOTOCATALYTIC TiO_2 VERSUS CARBON FOOTPRINT

Josef PECEN[a], Petra ZABLOUDILOVÁ[b], Miroslav ČEŠPIVA[b]

[a]*Czech University of Life Sciences Prague, Faculty of Tropical AgriSciences, Kamýcka 129, 165 21 Prague 6, Czech Republic, e-mail: pecen@its.czu.cz*

[b]*Research Institute of Agricultural Engineering, Drnovská 507, 161 01 Prague 6, Czech Republic, e-mail: petra.zabloudilova@vuzt.cz*

Abstract

The paper also focuses primarily on the opportunity to express and quantify changes in the properties of the internal environment of an object by using the value of the carbon footprint of the environment. It contains, among others, greenhouse gases and ammonia. Their concentration can be measured by a current experience can reduce the concentration of this example, the interior walls painted the color of the object with photocatalytic TiO_2. Comparing the values of carbon footprints of two identical objects or two identical parts of one object when one object or one of its parts is provided, for example, paint the walls with photocatalytic TiO_2 can obtain direct information on the effect of coating the walls with TiO_2. Similarly, changes in the carbon footprint of the internal environment of the building and to quantify the change in technology in the building or its structural modifications, including for example the ventilation system object. This allows primarily for the same or a similar type of object a degree of prediction of the outcome of the planned changes during their construction or renovation. To calculate the amount of CO_2 used standard calculator carbon footprint with equivalents for other gases than CO_2. A disadvantage so determined carbon footprint is the impact of any non-identical external conditions of the compared objects. On the contrary, the advantage is that the living conditions in the building assessed comprehensively, as a result of the interaction of several variables, as it actually is.

Keywords:

Carbon footprint, TiO_2 photocatalysis, laboratory testing, pig slurry, air quality

1. INTRODUCTION

This article explores the problems of polluted air which can be found inside farm buildings, most often stables and livestock barns. The article attempts to quantify the levels of pollution and explores methods by which these levels can be reduced. The pollution levels are quantified in relation to their carbon footprint. The carbon footprint is monitored and measured based on different parameters inside the buildings by utilising modified laboratory measuring equipment. At all times we are seeking to reduce the carbon footprint. The test environment comprises of animals who are kept in barns and stables for large parts of the day. It is important that the environment is, in the interest of animal welfare, made as harmless and pleasant as possible. The carbon footprint is expressed as a standard mass of CO_2 produced relative to selected test subject (for example, how many kilograms of CO_2 would be produced per one kilogram of animal weight).

The barn or stable environment contains NH_3 and other gases (e.g. CH_4, N_2O), which can magnify the greenhouse problem, and these have to be taken into account in the total carbon footprint calculation via their equivalents in CO_2. We are able to measure the concentrations of the various gases in the buildings internal atmosphere in a well-controlled and technically precise manner that also allows us to calculate the carbon footprint. Naturally the carbon footprint can be expressed in other ways but its quantification using the weight of CO_2 is the most standard procedure. To accurately calculate the carbon footprint we must take into account the many factors which will affect the carbon footprint value; i.e. size of building, the materials it is constructed from, lighting, ventilation, heating and specific alterations to the internal layout. We can then, based on modifications to the building and environment, quantify the effect these changes have on at least one test subject. In the public arena, it is the case that carbon footprint values are more meaningful than values relating to concentrations of greenhouse gasses in the atmosphere. Furthermore carbon footprint values allow comparisons between different specimens and the levels of pollution in different places if one follows the same methodology used to determine the relative levels. In practice it has been tried and tested by the authors of publications [3, 4], which show that using a common and consistent methodology, is necessary to achieve successful results. Due to the nature and inherent inaccuracies in the input data there is always a level of uncertainty in the calculated carbon footprint. At this time there is no equivalent replacement data available.

2. MATERIAL AND METHODS

The laboratory experiments used pig slurry that was collected when it was needed and the experiments were performed on the partially modified measuring equipment described in [5]. Identical weights of pig slurry were placed into two bowls. These were then placed, one into the experimental test tube and one into the reference test tube. Both test tubes have the same initial concentration of greenhouse gases and ammonia, in effect mimicking the real environment inside the barn. The interior of both test tubes was illuminated using linear fluorescent lamps of the same wattage. The linear fluorescent lamp in the test tube had a greater proportion of UV radiation (30% UV-A and 5% UV-B) compared to the reference linear fluorescent lamp in the reference test tube. The physical dimensions of both test tubes were identical so the actual illumination value on the inner surface of the reference and test tubes was virtually identical. The test tube had on its inner surface a coiled paper carrier. On one side it was painted with TiO_2 photo catalyst that served to significantly reduce the ammonia content inside the tube. The TiO_2 coating in the experimental part of the device was lit with the fluorescent lamp with a greater proportion of UV-B radiation. This caused a photolytic reaction that reduced the amount of ammonia in air contained within the tube. Flow velocity measurements were carried out on both test tubes in the range of 0.2 to 0.5 m/s and continuous monitoring was undertaken. The experiment lasted for 24 hours. Throughout this period the concentrations of individual gases (NH_3, CH_4, CO_2, N_2O) were measured. The carbon footprint was calculated using the different values from both test tubes caused by the ongoing TiO_2 photo catalytic reactions.

Based on the results of laboratory experiments with the photo catalytic coating, a pilot experiment was conducted using pigs in a barn. This experiment was carried out twice (the third planned experiment was not completed). For the purpose of the experiment the barn was physically divided into two identical parts with the same number of animals in each part. In the experimental part the walls were painted with photo catalytic TiO_2 and the lights were replaced with liner fluorescent lamps of the same wattage as in the control part but with a great proportion of UV radiation. The control part of the barn retained its original lighting and wall paint. Both parts of the barn were illuminated to the same intensity. In both parts the gas concentrations in the atmosphere were continuously measured and, using the difference between the two concentrations, a carbon footprint was calculated. Any difference between the two concentrations was caused by the TiO_2 photo catalytic reaction because in all other respects the experimental and control parts of the barn were the same or very similar.

Continuous measurement of gas concentrations was carried out using the analyzer 1412 Photoacoustic Multi Gas Monitor with 1309 The Multipoint Sampler The velocities of the air flow through the experimental and referential parts of the equipment were measured in accordance with CSN 12 4070 with an anemometer for low flow velocity measurements. The air temperature, relative humidity, pressure, and also the radiation intensity were monitored. All data results were released for statistical analysis.

3. RESULTS

Results of laboratory tests for seven repetitions are shown in Table 1 which only lists the differences in carbon footprint values between the reference and experimental parts of the measuring equipment for each test round. The value of the carbon footprint in the experimental part was always smaller, as could be expected. The difference in the values of carbon footprints of both parts of the measuring equipment in each retry of the experiment thus represents reduction of some greenhouse gases and especially ammonia. Given the small number of retries and a greater dispersion of the results, Table 1 lists also other medium values than the arithmetic average that estimates normal division of measured data and their greater number, which was not fulfilled. Table 2 therefore lists also reliability intervals (RI) for these medium values. All RIs are calculated on the level of significance amounting to α = 0.05. Table 2 shows that non-parametric statistical methods provide more relevant results.

Table 1 The difference in the values of the carbon footprint (Δ) when repeating the experiment in the laboratory

Opposite order	Repeat laboratory experiment							Mean differences				
	1	2	3	4	5	6	7	AP	GP	M	H.M	L.T.
Δ (%)	13.2	8.7	6.1	12.6	9.0	7.7	5.6	8.98	8.58	8.70	8.35	8.66

Table 2 SH and IS measured data set, calculated by different statistical method

	Marking the mean value				
Quantity	AP	GP	M	H.M.	L.T.
SH (%)	8.98	8.58	8.70	8.35	8.66
CI	6.03 – 11.93	6.33 – 11.62	6.24 – 11.16	7.41 – 9.28	6.29 – 11.69

Abbreviations used in Tables 1 and 2

Δ ....difference in the values of the carbon footprint between the two parts of the measurement of the individual attempts (the value of the carbon footprint in the reference section is 100 %)
AP ....arithmetic average
GP ....geometric mean
M ....median
H. M. ....Horn method of determining the mean value of the measured data
L.T. ......Lambda transformation
SH ....mean value of the sample mean file calculated by non-parametric statistical methods of measurement data
CI ....confidence interval is calculated for significance level α = 0.05

The results of pilot plant experiments are similar to the results from laboratory measuring. Until now, only two series of measuring in pilot plant conditions (two repetitions) have been completed. Lower concentration of the monitored gases and therefore smaller value of the carbon footprint was ascertained in the experimental part of the barn, where the walls were coated by a paint with TiO_2 and photocatalytic reaction probably took place. In the first round, the difference was 16.2 % and in the second run, it reached 11.3 %. The third retry has not been completed yet.

4. DISCUSSION

Selected verification procedure quantification indoor pollution farm buildings, barns and stables mainly using carbon footprint, proved to be correct. The actual value of the carbon footprint can be even using very creatively, depending on the choice [2, 3, 4]. The calculation of the carbon footprint is often modified and simplified to form a "carbon calculator" that is very accessible. In this case, was also used because it is based solely on the measured concentrations of greenhouse gases and ammonia in stables and in the laboratory. She was so used even before the measurements of concentrations of gases and ammonia in stables. The actual value of the carbon footprint for approximately the same operating conditions stable is never the same for these objects, as evidenced by the authors in the works [1, 2, 3]. The differences between the declared values are in units within a maximum of one order, which is a good match. The authors of the report [1] report the mean 1309 g CO_2/liter of milk produced, but on different farms, this value ranged from 832 g to 2808 g per liter of milk, for about the same technology. This is a good agreement with the author of the message in [3], which represents the value of the carbon footprint of dairy cows in the barn 1350 g CO_2 per liter of milk. Much depends on the methodology used, which can be a source of inaccuracy.

So, what is the value of the carbon footprint usually interpreted [4, 8, 9], so it is a broader concept expression pollution. The corresponding unit of pollution can be very unusual. In the experiment described in the article were contrary to verify whether it is possible by this method to express the difference in pollution interior of the object (or quantify) for a narrow range of changes in operating conditions of the object, in this case the stables. Because it is still an effort to reduce the concentration of ammonia in the barn if possible in a simple manner , was used for this purpose and TiO_2 photocatalytic reaction was measured directly difference in the value of the carbon footprint for experimental and referencerooms. This method has been widely published previously [6, 7, 8] and verified with different results, mostly positive. An essential prerequisite for the proper functioning of the method is also suitable lighting areas fitted coat with photocatalytic TiO_2. The minimum value of the illumination areas required for photocatalysis, is 30 to 40 mW/cm^2. It is generally observed, but must be applied light radiation with a larger UV radiation that causes a reaction. Another common fault is pollution painted surfaces and sometimes even more speed airflow around these areas. A thorough analysis of the conditions for the functioning of this method is in [7]. The laboratory method validation photocatalytic preparation was used whose detailed description is given in [5]. The carbon footprint of both parts of the product are listed in Table 1 and were first calculated the "carbon calculator”.

Given that this is a small number of measurements (small file) in the Table 1 and 2 include other than arithmetic mean diameter and their confidence intervals. It's not all automatically using the arithmetic mean as the mean value and assume a normal distribution of measured values file. For all other gases were used for conversion to CO_2 equivalents usual. The differences in carbon footprint can be caused by different characteristics of the input slurry preparation. It is very difficult to maintain exactly the same properties of slurry for a longer time, whereas it is a biological material. Repeated laboratory experiment confirmed that the value of the carbon footprint reflects changes in the process that correspond to the individual operations used in technology or changes in the process of any partial change the configuration in the building and the like. It thus allows the monitor in detail the effect of these singularities on the overall pollution of the environment and thus refine the technology used in terms of environmental pollution. Carbon footprint is only one of the indicators used and pollution is a universal means of expression harmfulness environment.

CONCLUSIONS

The results from previously conducted laboratory and pilot plant experiments can be summarized as follows :

- The carbon footprint was lower in all cases where the experimental part (the inside of the pipe or walls of the experimental barn) was coated by paint with TiO_2. At the same time, the minimum value of lighting of these surfaces by 30-40 mW/cm^2 fluorescent lights with higher share of UV radiation must have been ensured.
- The medium size of the difference in values between experimental reference part of the equipment or the barn was less than nine per cent in favor of the coating including TiO_2.
- In all cases, the value of the carbon footprint was calculated from the measured concentration of the monitored gases and ammonia, and this concentration was always lower in the premises with the TiO_2 coating.
- The value of the carbon footprint can be also characterized by the difference in environmental

pollution caused by individual technological operations.

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