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Acoustical performance of samples prepared with cigarette butts

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ABSTRACT

Cigarette butts which are majorly composed of cellulose acetate are an undesirable material waste mostly present in human debris and with little prospects for being recycled. In this paper, a new use of this material as an absorbing material is proposed and analysed. Samples prepared with used and unused cigarette butts were assessed according to ISO 10534–2: 1998 standard. Preliminary studies referring to the influence of the length of butts, their provenance (used or unused), the effects of compression, and comparison with other commercial materials are presented.

The obtained results are very promising, showing high sound absorption performance. The performance of these materials compared with some commercial sound absorbers indicates that they could be used as possible alternatives. In any case, further studies are necessary and some of them are proposed herein.

1. Introduction

After centuries of evolution, humans have acquired some habits that, although pervasive, are clearly unhealthy. One of them is smoking, of which the harmful consequences to human health (both for smokers and people who inhale cigarette smoke) are clearly known.

In an attempt to reduce the incidence of diseases in smokers, cigarette filters were introduced in the middle of the 20th century. Thus, the consumption of cigarettes with filters increased from about 1% (mid 1950s) to 98% at the beginning of the 21st century [1,2], partly helped by published studies showing the decrease of lung cancer in filter cigarette smokers compared with unfiltered cigarette smokers [2].

Filters used for cigarettes are mostly composed of cellulose acetate, a substance which is not biodegradable and the photodegradation of which takes several months (even this photodegradation is only partial: the filters are broken into smaller pieces). However, to date proposed alternatives have not been successful, due to problems of dissemination or lack of acceptance by smokers [3]. Thus, the existence of filters in cigarettes has led to a new concern: what can we do with the used filters? This question is even more relevant when one considers that a large proportion of smokers throws their cigarette butts on the ground (one third, according to some US studies [4]) and given that annual global cigarette consumption is enormous (it was higher than five billion cigarettes in 1995 [5]). In fact, in studies of the debris composition of our environment (streets, beaches, etc.) or in places of garbage collection (bins, containers, etc.) butts are usually the element which has the largest numerical quantity and the greatest weight [6–8]. Toxicity due to cigarette butts makes these problems worse. Thus, once smoked, the filters of cigarettes accumulate substances from the tobacco and/or its combustion which are easily dissolved in water, making it toxic to various organisms [1,9,10].

A contribution to decreasing the number of cigarette butts found on our streets, beaches, and in our garbage, would be to find an alternative use or a way of recycling these butts. Thus, in the recent decades some authors have proposed some different uses for smoked butts (such as supercapacitors [11] or as part of the composition of bricks [12]) or for their washing waters (such as insecticide [13] or chemical inhibitors [14]).

As a new contribution to these recycling initiatives, in this paper preliminary works referring to the use of cigarette butts as sound absorbing material (due to their porous character [15]) are presented and further steps in this research line are proposed.

Although in the last decades sound absorption in buildings has been carried out mostly with rock and industrially manufactured mineral wools, in recent years some alternative materials have been proposed, many of them natural [16–19]. The acoustic behaviour of fibrous and porous material has been deeply studied in the last decades. Indeed several theoretical and/or empirical models have been proposed to explain this acoustic behaviour. One of

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Fig. 1. Disposition of the impedance tube for the measurements.

the most used models is the one proposed by Delany and Bazley [20], an empirical model which uses the flow resistivity as a relevant parameter. For fibrous materials, improvements to this model have been proposed by other researchers [21–23]. Other models, based on the porosity of the samples have also been proposed for fibrous and porous materials [24]. There are other models based on the assumption that the porous absorber is like a rigid frame media and the pore geometry is cylindrical. In these models, two complex quantities, the equivalent dynamic density and the equivalent dynamic bulk modulus describe the acoustical performance of the sound porous absorber through some non-acoustical parameters such as porosity, tortuosity, flow resistivity or shape factor. Energy is dissipated, mainly, by heat exchange between the air and the porous skeletal, and by viscous friction in the effective fluid in the porous structure [25,26]. Finally, 'phenomenological' models study sound propagation through porous materials with very complex pore shapes where it is nearly impossible to propose exact models. In these models, different formulations for effective density and compressibility modulus are given and they include some parameters that depend on the pore geometry (i.e. cross-section of the pore) [27,28].

The works described in this paper try to contribute both to the recycling of cigarette butts and to the proposal of alternative materials for sound absorption. As far as we know, for these residues no similar studies to the one proposed have been previously published.

2. Materials and methods

2.1. Instrumentation for acoustic measurements

To evaluate the sound absorption coefficient of the different samples, measurements were carried out using an impedance tube. Impedance tube measurements are based on the two-microphone transfer-function method according to the standard procedure detailed in the ISO 10534–2 standard [29]. Using this method, it is possible to obtain fast measurements of normal incident parameters using small samples.

The measurements were made using the Brüel & Kjær Impedance Tube Kit (Type 4206), installed in a vertical position (see Fig. 1) to allow the acoustic properties of non-consolidated samples to be easily measured, and two one quarter inch Condenser Microphones (Type 4187). The signals were analysed with a portable Brüel & Kjær PULSE System with four input data channels (Type 3560-C). A sample holder of 29 mm in diameter was used (with validity in the frequency range of 500 Hz to 6.4 kHz).

Table 1
Characteristics of measured samples.

Sample	Number of butts/status	Length (mm)	Diameter (mm)	Density (kg/m^3)	Porosity
A	10/used	21.1 ± 0.5	7.2 ± 0.4	112 ± 3	0.943
B	10/used	14.2 ± 0.3	8.1 ± 0.2	162 ± 4	0.927
C	10/used	14.6 ± 0.1	8.0 ± 0.2	156 ± 3	0.929
D	10/unused	11.5 ± 0.4	7.1 ± 0.2	125 ± 5	0.944
E	10/purchased	13.9 ± 0.3	6.8 ± 0.2	103 ± 3	0.949
F	10/purchased	28.6 ± 0.5	7.0 ± 0.2	–	–

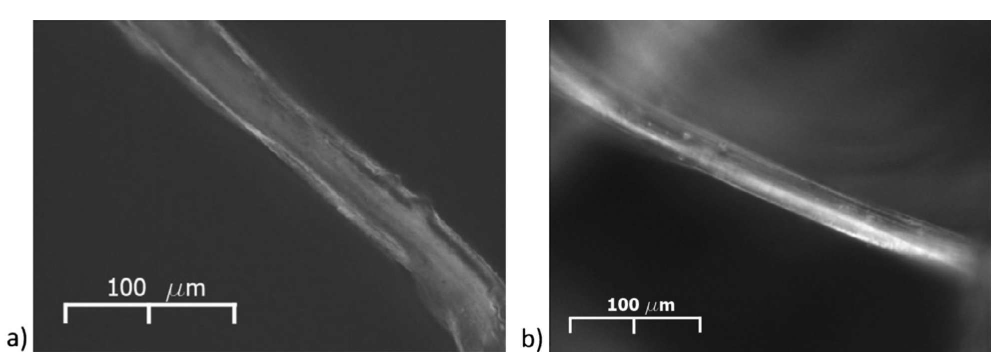

Fig. 2. Confocal microscopy images of fibres of cigarette butts. (a) Non-used cigarette butt. (b) Used cigarette butts.