Determination of the Odour Adsorption Behaviour of Wool

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ABSTRACT

In this study, the adsorption/desorption behaviours of water vapor on wool, as well as of the redolents, such as acetic acid and benzaldehyde, have been investigated. For this purpose, static and dynamic experiments were carried out. Static experiments were conducted to model stagnant environments. In the experiments, wool came into contact with the material to be adsorbed or dry air and the weight increase/decrease was recorded for a certain period of time. The results obtained showed that the wool adsorbed the benzaldehyde very little, whereas the adsorbed amount and the rate were abundantly increased for acetic acid under the same conditions. From these findings, the adsorption capacity of wool for the redolents was tentatively ranked in accordance with their adsorbed amounts as acetic acid >water>benzaldehyde.

KEYWORDS

Wool, fibre, odour, adsorption, desorption, redolent, acetic acid, benzaldehyde

INTRODUCTION

Today, environmental pollution and energy scarcity are some of the most important problems for humanity. Environmental problems caused by industrial manufacturing can be studied under 4 classes: air, water, solid waste pollution and noise [1]. Malodour is also a part of air pollution. Solution methods of environmental problems are [2, 3, 4]

- cleaner technologies,
- reuse,
- recycling,
- recovery,
- storage without recycling,
- disposal by burning.

In this study, the use of waste wool and odour management was examined from two different viewpoints. The wool, which is a solid waste, has a new application in the field of odour management and has therefore gained economical value. On the other hand, the control of body odour is an important issue because of clothing comfort. The results in this paper can give an idea about the effect of wool on the body odour control.

Odour is a feeling given by odorant molecules dissolved in air. A molecule which is odorant achieves the following conditions [5]:

- It has to be fastened to an odorant receptor.
- It has to result in the odorant receptor transmitting the recognition to the brain.
- The brain has to admit that it is a signal which can be clarified.

The reason for the bad smell of things is that it is malodorous because of its nature, or it starts to spread bad smell with decomposition. Sources of indoor pollution are shown in Figure 1 [6]. Gasses emitting some bad odour can show poison effect at high concentration. This adverse situation requires the removal of malodorous gasses. Besides, the smell affects people in a number of ways. Strong, unpleasant and repulsive smells can prevent a person from enjoying life if they are frequent and/or persistent. Main factors related to sensory scent anxiety: repellency, duration of exposure to the olfactory, the frequency of the fragrance, the tolerance and expectation of the recipient. Unpleasant odours are a source of concern about air quality and affect people's daily living conditions, and they also warn people of danger. The ever-increasing global population and industrialization levels deteriorate the air quality in and around the emission sources and thus the requisition for sustainable volatile organic compounds (VOC) odour control technologies become more and more important [6, 7].

The external atmosphere, heating type, efficiency of ventilation and the materials used in construction of the building itself which can emit VOC affect the quality of indoor air. The factors like temperature, humidity, and air flow have an effect on odour retention and odour release by textile materials, as well as formation of odour. [8, 9, 10].

There are many studies and patents reporting the works done on the removal of smell through various methods involving the evaluation of an apparatus for this aim. In the studies, the materials managing the odour of indoor air are very different from each other. For instance, a newly isolated autotrophic bacterium, Thiobacillus thioparus DW44, which is capable of degrading sulphur-containing gasses, was inoculated into a pilot-scale peat biofilter to treat the exhaust gas from a night soil treatment plant [11]. Activated carbon, ozonation and aerated biofilters were applied to eliminate odour-causing compounds that occur in waste-water and effluents from the activated sludge process [12].

A field experiment was conducted using a full-scale ceramic biofilter (approximately 150 m^3/min) in order to determine the potential of biofiltration in removing malodorous gasses from composting facilities. It was estimated that the deodorization using this ceramic biofilter was successfully carried out to remove the odour emitted from composting facilities [13] (Figure 1.).

Stefanowski et al. (2015; 2016) examined the effect of an MDF panel on mould growth and the absorption of the VOCs. The MDF panel was composed of a mix of pine, fir and spruce wood chips and a urea-formal-dehyde Resin. VOC scavengers in the MDF panel were walnut shells and peanut shells in three different loading percentages. The solid pine wood was the control sample. The VOCs were toluene, limonene and formaldehyde. It was found that the MDF panel, modified by the addition of walnut shell or peanut shell, absorbs formaldehyde, toluene and limonene [14, 15].

Stefanowski et al. (2017) studied lignocellulosic nut waste as an absorbent for formaldehyde. The study concluded that the nitrogen content of the waste affected formaldehyde absorption positively [16].

Silva et al. reported that the walnut shell in the MDF panel increased the specific surface area of the panel because of the porous surface of the walnut shell. And MDF panels containing walnut shell absorbed VOCs easily [17].

Additionally, there are many patents appearing in other studies on developing novel methods, compositions and apparatus for the removal of odour [18-24]. These evaluated novel compositions and methods for

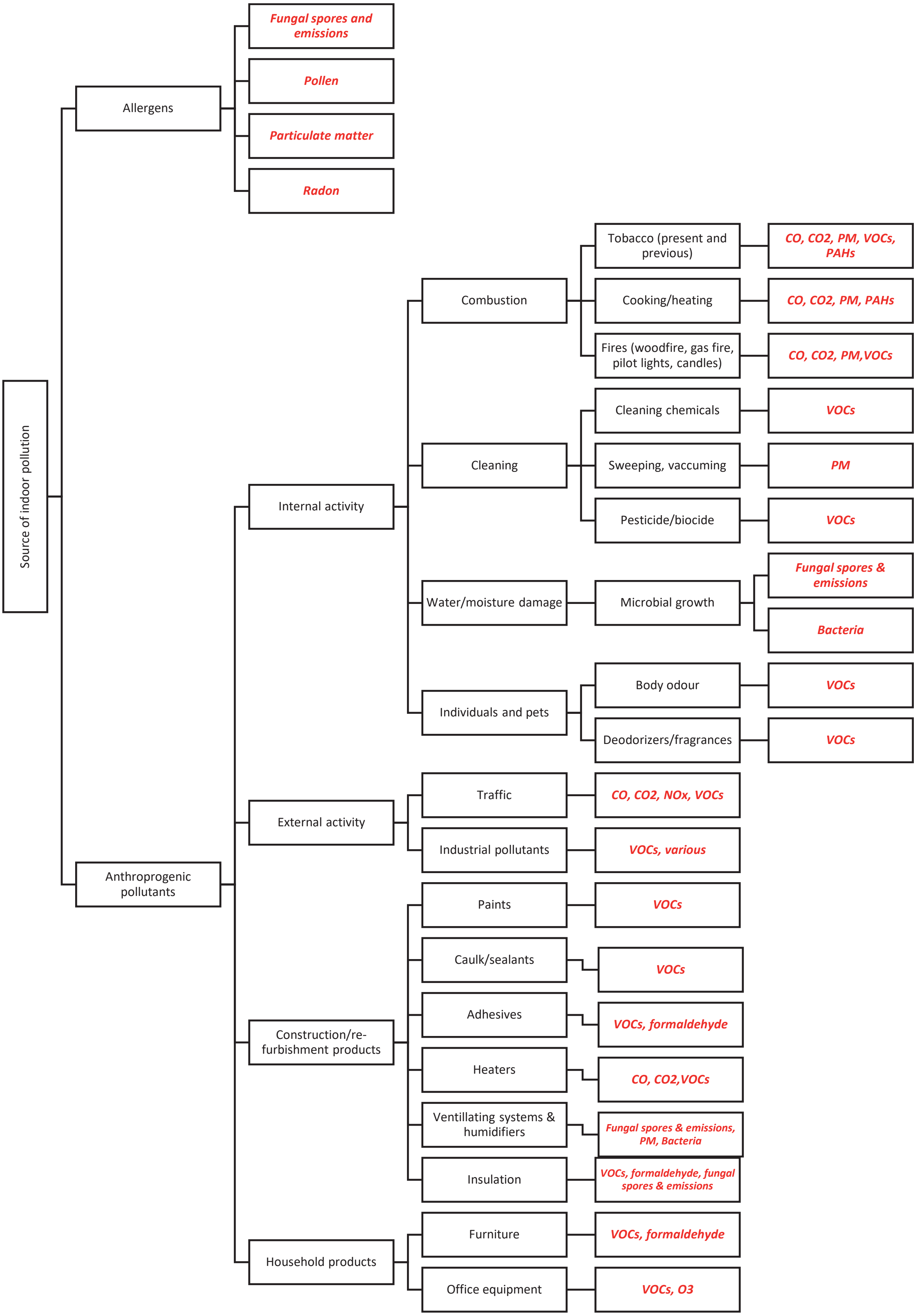

Figure 1. Sources of indoor pollution [6]

reducing odour contain at least one synthetic zeolite, at least one acid and at least one substance selected from a metal oxide, metal, or salt of a metal or metal oxide. A wide range of odours, including ammonia and sulphurous odours, may be controlled by contacting an effective amount of the above composition with the article, substance or environment that emits the undesired odour [18].

An apparatus for delivering an odour-reducing chemical to a toilet bowl, comprising of a pressurized source of odour-reducing chemicals and a valve for selectively releasing odour-reducing chemicals from the pressurized source, communicatively connected to the pressurized source of odour-reducing chemicals, was improved on [19].

A process and an apparatus for treating gasses containing odoriferous constituents have been improved on. The process was carried out by condensation [20].

An invention for a novel odour-removing and deodorizing composition, which contains a hydrolysate of keratin material as its effective component, was improved on. The hydrolysis of keratin material may be affected by any known methods using acid, alkali or enzyme [21].

After aerating sewage sludge in a composting process, a stream of process air is treated to remove odours therefrom by injecting an atomized mixture of dilute sulfuric acid and dilute surfactant into the airstream to remove ammonia and odorous organic compounds therefrom [22].

There is a research about the compositions useful for maintaining the impression of cleanliness of a carpet (that is, its scent and appearance) over an extended time despite occurrences that might damage the carpet surface. The composition, which includes an antimicrobial agent, an enzyme inhibitor, and an odour-reacting compound, can be used by a consumer to remove contaminants from the carpet and to prevent the odour associated with the decomposition of future contamination [23].

The development of an odour and moisture-removing apparatus and a method for manufacturing the same, suitable for insertion in a shoe or a boot, is another invention reported in the studies. The apparatus includes an outer shell which encloses layers of a woven porous fabric. A porous and absorbent felted material such as “silence cloth” is enclosed between the top/bottom layers and the layers holding the desiccant material. Further, a desiccant material is included [24].

Wool is a well-known and a common animal fibre. As a result of its complex physical and chemical structure, wool is odour-resistant, flame-retardant, breathable and naturally antibacterial [9, 25].

Wool absorbs and binds with many of the noxious compounds in the polluted indoor air because of the side chains of the various amino acids in its chemical structure. It can react with disulphide bonds in wool due to the reductive structure of the sulphur dioxide. The sulphitolysis reaction is irreversible. Wool is very useful for controlling body odour, too [9].

The build-up and release of odour, generated by the usage, is an undesirable feature for textile items. The odour arising from the secretions of the human body like the sweat glands, urine, faeces, skin, and genitals becomes an important problem for textile items due to its adherence and persistence within textiles (Figure 2). Eccrine and apocrine sweat glands are the main physiological contributors to body odour; however, the secretions from sebaceous glands, found in different areas of the body, promote to odour. Besides, ingesting foods (garlic, onions, etc.), alcohol and some therapeutic drugs strengthen the body odour [10] (Figure 2.).

A highly complex and versatile odour problem resides within textiles. Textile materials can absorb and subsequently release volatile substances in gas form. These substances, called odorants, are realized by the olfactory organ. The non-odorous compounds are transformed into odorous compounds by some specific microorganisms under prolonged dampness conditions. Odours or precursors can be adsorbed to textile materials from liquid media such as sweat and washing water. Hydrophilicity of textile materials has effect on odour sorption. Fibres can sorb odorous substances directly and desorb them in a different amount [10].

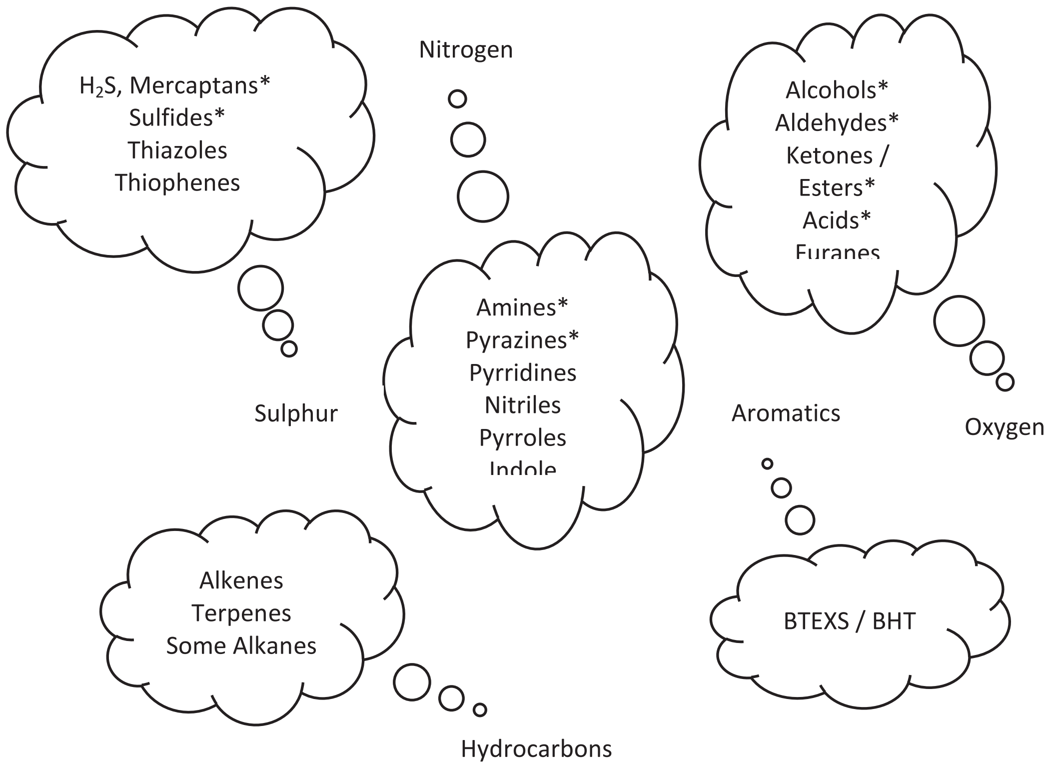

Figure 2. Potentially odorant substances at the interface of human skin and textile [26]

Woollen clothes absorb body odours and trap them within the fibre until washing because of the complex chemical and physical structure of wool. Perspiration swells the fibres and odour molecules diffuse into the structure of wool. Then the sorbed moisture evaporates and the swollen fibres shrink. As a result of shrinking of the wool fibres, the odour molecules are trapped within the structure. During the washing, the fibres swell and odour molecules are released into washing water [9].

The sorption of water vapor, odorants and other harmful substances takes place by different mechanisms. Additionally, there are differences in behaviour between various wool breeds. Ormondroyd et al. [8] concluded that these differences cannot be directly assigned to the variation in fibre composition because the history and the treatments of different fibre types is not known. Many of the harmful substances in indoor air are absorbed by wool fibres through the interaction with the amino acid side chains of the wool fibres [9].

The Dynamic Vapour Sorption (DVS) techniques are the most commonly used methods among the methods previously mentioned [27, 28, 29]. The method used in this study to remove bad smells using waste wool is cheap and easy, and also harmless. Pure acetic acid and benzaldehyde are used as odorants.

MATERIALS AND METHODS

In this study, acetic acid and benzaldehyde were used as odorants and silica gel as a drying agent. The odorants were used as supplied. Acetic acid was obtained from UPARC with a minimum of 99.5 % purity. Benzaldehyde was obtained from Merck with a minimum of 99 % purity. Before all the experiments, wool sliver, cut into a 25 cm piece, was brought to constant weight by drying over a silica gel layer. The experiments were conducted in an air-conditioned room at 20°C.

Dynamic experiments

Dynamic method is an accelerated test method and it is applied in order to determine the transport of the smell on the wool by the air current and the absorptivity of the odour in a short time. For this purpose, the device given in Figure 3 was installed and used.

The air at a rate of 56 ml/min was conducted first through the column containing odorant and over the wool placed in a U-tube. The weight of wool, the air flow rate, relative humidity and temperature were recorded at certain time intervals. The experiments were ended when the change in weight was negligible. The same experimental procedure was followed for the desorption but odorant column was replaced by silica gel.

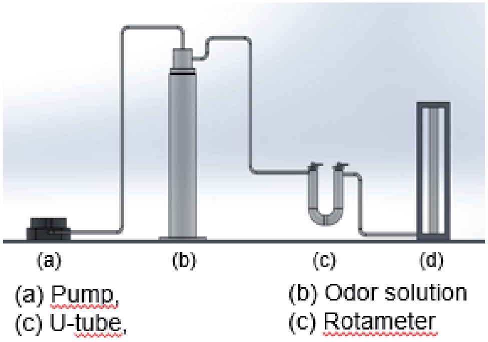

Figure 3. Dynamic experiments

Static experiments

The static experiments were conducted to determine the odour-absorptive capacity of wool under static conditions and a desiccator was used to simulate a stagnant medium (Figure 4). The dry wool was placed into a desiccator containing odorant and weighed at regular intervals and relative humidity and temperature were recorded. When the change in the weight of the sample was insignificant the experiment was ended and the drying cycle was started in another desiccator containing silica gel.

Figure 4. Static experiments

RESULTS AND DISCUSSION

The results of the dynamic and static experiments were given in Figures 5a, 5b, 6a, 6b, 7 and 8. The wool has considerable adsorption capacity for acetic acid and benzaldehyde, which emit unpleasant odours. As shown in Figures, the adsorbed amount of acetic acid is the highest and this could be explained by the existence of the interaction between COOH group of acid and NH2 group of wool. The comparison of adsorption behaviours of used and unused wools showed that the adsorption capacity of the used material was slightly decreased.

Dynamic experiments

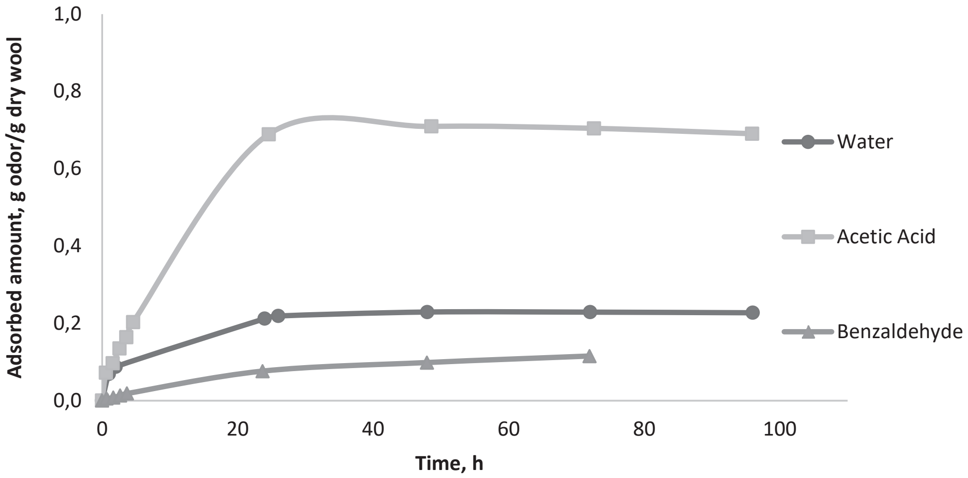

Figure 5a. Adsorption of various odorants on wool.

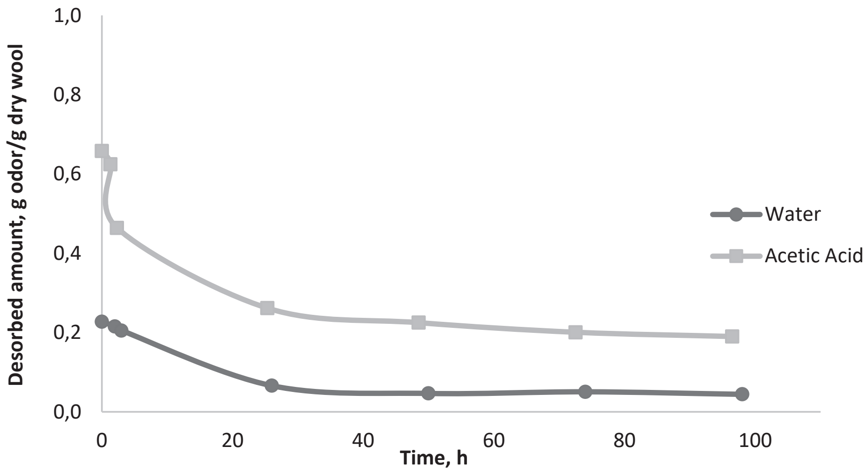

Figure 5b. Desorption of various odorants on wool.

Static Experiments

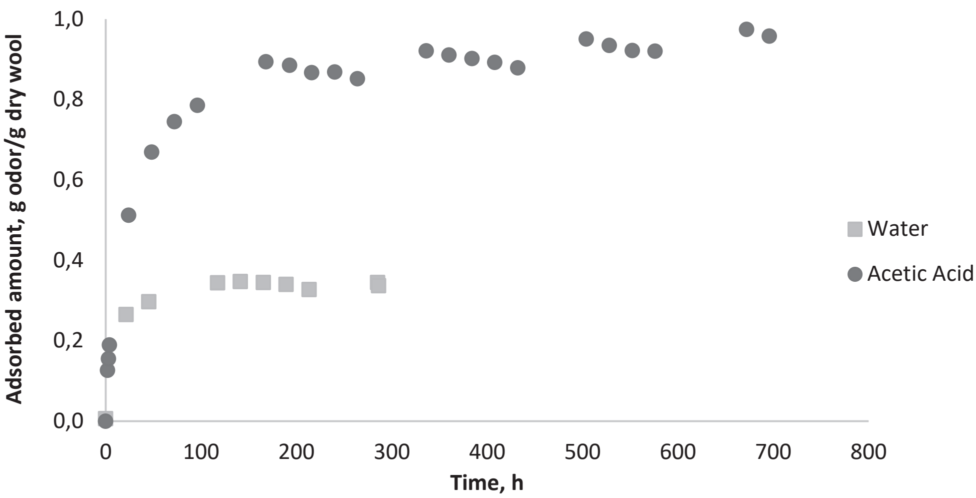

Figure 6a. Adsorption of various materials on wool.

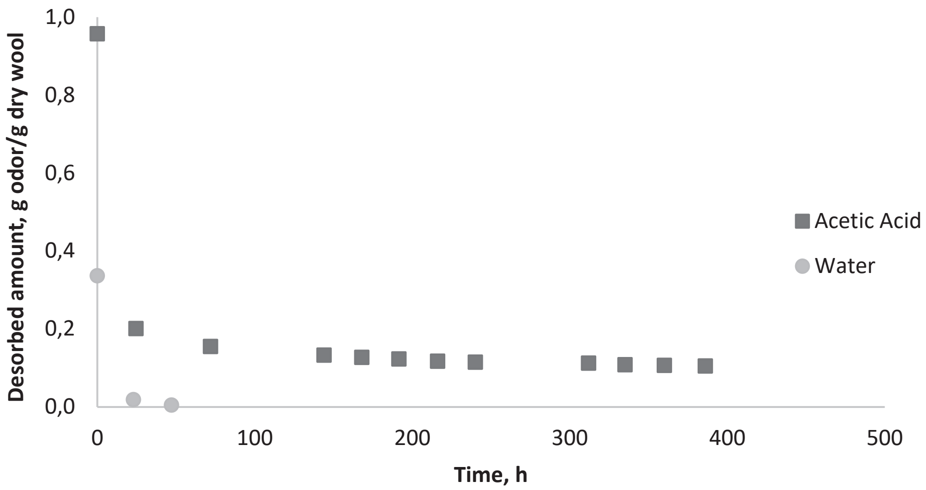

Figure 6b. Desorption of various materials on wool

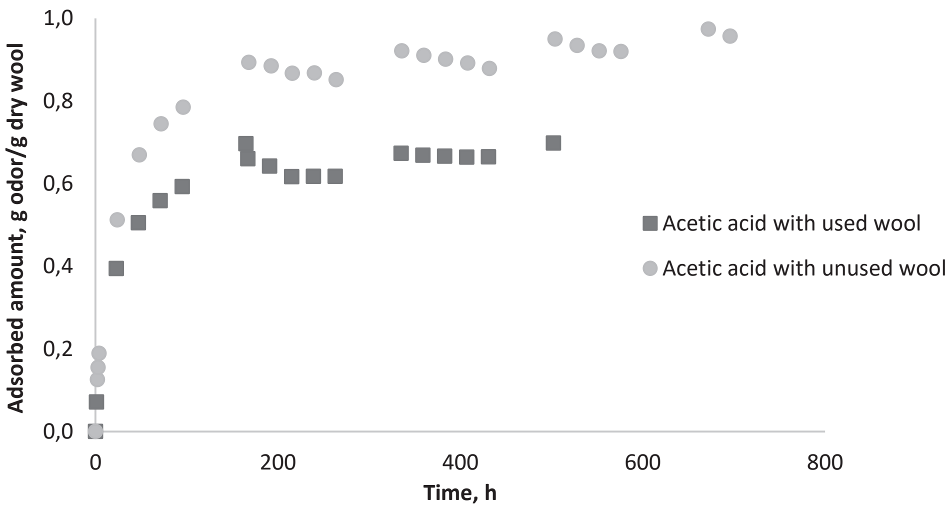

Figure 7. Comparison of the adsorption behaviour of unused wool with that of the wool used in the adsorption

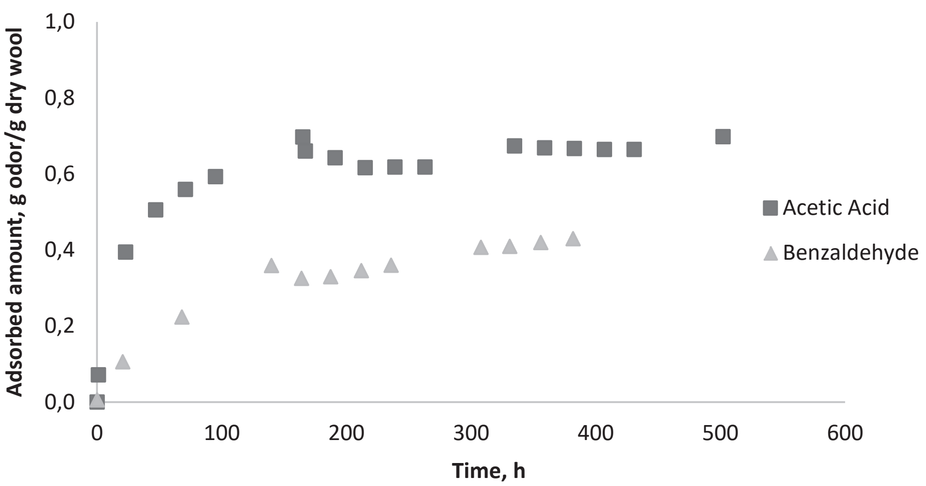

Figure 8. Adsorption of various odorants on wool

CONCLUSION

The results of the experiments showed that wool has a potential for removing malodorous substances. A comparison of the equilibrium-adsorbed amounts and the time indicated that the benzaldehyde has the smallest adsorption rate and the equilibrium-adsorbed amount was 0.11 g odour / g dry wool for 72 h contact time. For water and acetic acid, these values were 0.22 g moisture / g dry wool and 26 h and 0.69 g odour/g dry wool and 25 h, respectively. The adsorption capacity of wool was slightly decreased when it is reused after regeneration carried out by the desorption in air.

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