Validity of detection of microbial growth in buildings by trained dogs

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Abstract

Microbial growth in buildings may evoke respiratory and other symptoms in the occupants and promote decay of construction materials. The decay in wood is usually caused by dry-rot fungus, leading to the decomposition of cellulose and lignin. There are also some mold fungi and bacteria that can use wood as a nutrient. In this study, two trained dogs were used to detect microbial growth present in buildings. The rot fungi Serpula lacrymans, Coniophora puteana and Antrodia sinuosa were used in the training. In addition to decay samples, pieces of healthy birch, pine and imbued wood were used as controls. Another experiment was made using bacteria (Streptomyces sp.). In these experiments, a total of 100 decay, 75 control and 25 bacteria samples were used. The dogs detected 75% of the decay and 60% of the bacteria samples. Some (0–24%) control samples were also expressed as positive. Since the dogs identified also the bacteria samples without any specific training, a new test with some mold strains (Cladosporium, Botrytis, Trichoderma, Penicillium, Aspergillus) was carried out. The dogs found all the decay, mold and bacteria samples but only one sample of healthy wood. The use of dogs to detect mold or decay damage appears to have high specificity and high positive predictive value, but low sensitivity. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Moldy buildings; Microbial growth detection; Dogs

1. Introduction

Bacteria, mold and fungi are capable of causing decay of wood and other construction materials. The trend to build new homes that are energy efficient and convert old houses for energy conservation has led to an explosion in mold-related problems over the past few years. These buildings may be susceptible to suffer structural damage by bacteria and molds (Viitanen, 1996). In addition, spores, dust and decomposing material can cause allergy and other symptoms in the inhabitants of moldy buildings (Samson et al., 1994; Miller, 1992).

The detection methods for decay damage are based on sensory evaluation, microbial sampling from the surfaces or ambient air or measurement of moisture content. All of these are indirect methods and suffer from limitations. Quite often, the damage is not visible on the surface of the material, which makes it difficult, even impossible, to locate the damage. Yet, before one starts to dismantle suspect structures, it is essential to know where to start the search.

The idea of using dog in flavour validation, forensic line-ups and to detect drugs, minerals, human remains or other hidden objects is not new (Rogers et al., 1967; Schoon, 1998; Komar, 1999). The dog has an excellent sense of smell, and as a social animal, it has a need to please the pack leader, i.e. its owner or handler. So far, scientific evidence on validity and success rate of using canine sense of smell is scarce and causes disagreement (Brisbin et al., 2000; Smith et al., 2001). Mold detecting dogs have been trained in both Sweden and Denmark (Davner, 1986; Ammer, 1985). However, the success of the training and the consequent ability to reliably detect molds remains to be documented. The aim of this study was to assess the ability of trained dogs to locate decay sites and molds in buildings.

2. Materials and methods

2.1. Dogs

Two female Labrador retrievers were used in the study. The dogs were 6 and 2 years old, and they were taught in
basic obedience by the dogs’ trainer prior to the specific training in microbial growth detection in buildings.

2.2. Fungi and bacteria used in training and detection

The microbes used in the training were rot fungi (*Serpula lacrymans*, *Coniophora puteana* and *Antrodia sinuosa*). The strains were identified by and obtained from the Wood Laboratory, Technical Research Centre of Finland (Espoo, Finland). The fungi were cultured on small pieces of pine-wood. Some other microbes, typical building “molds”, were also used (five fungi, *Cladosporium herbarum*, *Trichoderma viride*, *Botrytis cinerea*, *Penicillium verrucosum*, *Aspergillus niger*, and five bacterial strains of *Streptomyces* sp.). The fungi were cultured on malt extract agar (Difco Laboratories, Detroit, MI, USA) and the bacteria on tryptone–yeast–glucose agar (TYG) at room temperature for 7 days.

2.3. Training

First, a sample inoculated with each of the strains was introduced to the dogs before being hidden somewhere in the house, and the dogs were told to “search”. After daily training sessions for 2 weeks, the sample was no longer presented to the dogs, but they were readily asked to “search”. In the third phase, several samples were hidden around the house simultaneously. The location of different intensities of odor was tested by hiding several samples in one place and a single sample in another site. Tasks with no positive samples were included as well.

The samples were hidden on the floor along the walls and were covered with 2-m-long pieces of pine timber. When the dogs found the sample, they scratched the plank. This represented a spontaneous reaction, a reaction not taught to the dogs. Small pieces of bread were used as rewards. The training took a total of 3 months.

2.4. Experiments

The trials were carried out in the trainer’s home, in two buildings unfamiliar to the dogs: in a school classroom and in a university library. Altogether, three series were carried out. The first series of five experiments consisted of 10 samples of wood with cultures and 10 pieces of undamaged, dry wood (pine, birch and imbued wood), all hidden simultaneously. The second series of five experiments consisted of 10 samples of inoculated wood, 5 samples of bacteria and 5 samples of healthy wood, which were also hidden at the same time. In the third set of 42 experiments, two samples were hidden simultaneously, one inoculated piece and one healthy wood sample. All the samples were placed on the floor using gloves and covered with an object (table, shelf) to prevent visibility.

In the first series of experiments, the person who hid the samples was familiar to the dogs. The other 100 samples were hidden by a person unknown to the dogs. Both assistants walked all over the area to misguide the dogs.

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**Table 1**

<table>
<thead>
<tr>
<th>A. sinuosa</th>
<th>S. lacrymans</th>
<th>C. puteana</th>
<th>Bacteria</th>
<th>Birch</th>
<th>Pine</th>
<th>Imbued wood</th>
<th>Mold</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of samples</td>
<td>29</td>
<td>39</td>
<td>41</td>
<td>40</td>
<td>68</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Dog 1 (%)</td>
<td>97</td>
<td>77</td>
<td>68</td>
<td>75</td>
<td>6</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Dog 2 (%)</td>
<td>90</td>
<td>64</td>
<td>71</td>
<td>73</td>
<td>6</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Mean (%)</td>
<td>94</td>
<td>71</td>
<td>70</td>
<td>74</td>
<td>6</td>
<td>2</td>
<td>20</td>
</tr>
</tbody>
</table>

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Fig. 1. Percentage of samples expressed as positive by the dogs in all three series (Bact. = bacteria, Im.wood = imbued wood).
In the first two series of experiments, the dog trainer conducted the search with the dogs without knowing where the samples were hidden to prevent the dogs from receiving any postural clues from the trainer. In the third series of experiments, the trainer did not walk with the dogs. Between the first and second series of experiment, there was a period of 1 month when the dogs did not practice at all. The third period at home started immediately after the second series of experiment.

2.5. Statistical methods

The test of proportional contingent was used as the statistical test. Sensitivity, specificity, and positive and negative predictive value indexes were calculated from the data.

3. Results

3.1. Series 1 and 2

Dog 1 identified 79% of samples of decayed wood, 60% of samples containing bacteria but also 13% of samples of undamaged wood. Her success in detecting decayed wood was significantly better than that of detecting bacteria \((z = 8.34, P < .001)\), while success in detecting bacteria was better than detecting undamaged wood \((z = 1.72, P < .05)\).

Dog 2 found 72% of samples of decayed wood, 56% of samples of bacteria but also 12% of samples of healthy wood. The difference between samples of decayed wood and samples of undamaged wood was significant \((z = 7.75 \text{ and } P < .001)\). There was no statistical difference between the ability of this dog to detect samples of decayed wood and bacteria.

3.2. Series 3

When tested at home using only two samples, one of decayed wood, mold or bacteria and one of healthy wood at the same time, the dogs expressed all the samples of decayed wood, mold and bacteria as positive, whereas none of the healthy wood samples evoked positive reaction. In all three series, there was no statistical difference between the dogs. The results of all three series are tabulated in Table 1. Fig. 1 illustrates the percentage of samples that the dogs detected in all three series.

Fig. 2 shows the samples found by one or both dogs in the same experiment. For example 78.8% of all of the found decay samples were found by both dogs and 21.2% of the decay samples were found by only one dog.

The sensitivity of the method to detect mold and decay damage was calculated as 75.0% (219/292) and its specificity in 90.1% (173/192). The positive predictive value of the method was 92.0% (219/238), while the negative predictive value was 70.3% (173/246). The values in parentheses are derived from summarized results in Table 2.

| Table 2 | Summary of all correct and incorrect detections \((n=484)\) of microbial contamination by dogs |
|---|---|---|
| | Correct detection | Incorrect detection | Total |
| Samples with microbial growth | 219 | 73 | 292 |
| Samples without microbial growth | 173 | 19 | 192 |
| Total | 392 | 92 | 484 |

Fig. 2. Percentage of samples expressed as positive by either one or both dogs.
4. Discussion

In humans, the sense of smell is rather poor. Individuals can live for long periods in a moldy building without noticing its distinct odour and may ultimately live there long enough to suffer health problems. In contrast, dogs as a species are renowned for their sense of smell. This is due to the fact that even though human and canine olfactory receptors are similar, dogs have many more receptors (Moulton et al., 1960; Adrian, 1956). The use of dogs in the workplace is, indeed, frequently based on the species’ well-developed sense of smell.

Labrador retrievers are commonly used as guide, drug and police dogs, probably because they are easy to train. In this study, two Labs were trained for 3 months. In Sweden, where dogs are trained professionally by the state dog school, the training takes 6 months. One cannot state whether the Swedish “mold dogs” would perform differently since we are unaware of any reports on their performance in systematic studies.

Mold detection by dogs can be compared with line-up detection of suspects, since like each individual, all species of microbes seem to give off unique emissions, i.e. scent (Korpi et al., 1999). In buildings, the smell of the microbe is the signal that is to be detected, while emissions of healthy materials represent the background noise. Paints, glues and other chemicals present in the building further make the picture confusing and make the task of the dogs more complicated. Moreover, standard timber in the Nordic countries is either pine or spruce, which are loaded with volatile organic compounds (Nevalainen and Vartiainen, 1996).

Overall, the dogs were able to detect 75.0% (sensitivity) of the samples with microbial growth. In this study, the inability of a dog to find a positive sample with decay and bacteria, i.e. a false negative result, may be due to drying of the samples, since emissions for detection are higher with fresh and moist than with dry samples. This situation is different from a line-up, where dogs are seeking an individual via that person’s smell, but is analogous to detection of a group of drugs. The sensitivity can be considered as only moderate, and attempts should be made to improve it.

Clearly, false negative findings can lead to major financial losses, not to mention embarrassing situations and loss of credibility. However, the problem of false negatives seems to be more common than the problem of false positive in forensic sciences in general (Schoon, 1998), as was the case in this study as well.

False positive detection is low, as indicated by high specificity (90.1%) and high positive predictive value (92.0%) of the method. Some of apparent false positives could be traced to mistakes like not changing the gloves between handling decayed and healthy wood or keeping the samples of decayed wood on a table where a sample of healthy wood was subsequently hidden. False positives may cause major unnecessary dismantling of building structures, hence, it is advantageous that they occur in no more than 10% of the cases.

In this study, the dogs gave a positive reaction more often to undamaged birch or imbued wood than to undamaged pine. Only Dog 2 gave any positive reaction to pine (4%). All of these materials can be assumed to have their own smell, which could be why they confused the dogs. Birch is not commonly used as a building material and imbued wood is used only for moisture prone parts, therefore, in real-life detection situations, they should not be such a major problem.

Why the dogs also detected the bacteria, as well as mold, is unclear. One can assume that the smell is similar and definitely different from healthy wood. It is also possible that the dogs learned to spot them during the tests. Because the trainer did not know whether the dogs were detecting decay or something else, she had to rely on the dogs for training reasons and praise them every time they reacted to something.

When testing was carried out at home, the real samples were found quite well because the area was small and there were fewer strange smells. In addition, two samples hidden at the same time meant that the test was easier for the dogs, as can be seen in Fig. 1.

The dog should practice to maintain its skills. This study shows that a break of one month led to a difference between Tests 1 and 2. It seems that the skill had not disappeared, but it had lessened. On the other hand, the resting period had a positive effect, the dogs did work more eagerly after their break.

When searching in a real house, the dog has to also learn to cope with those situations when there is no decay or mold present. The dog must always be praised for its search even when nothing is found. However, if the dog finds something, a sample should occasionally be analysed in a laboratory as a quality assurance.

In conclusion, this study shows that it is possible to train dogs to reliably detect mold and decay damage in buildings. The method’s weakness seems to be the moderate sensitivity and negative predictive values, which are effectively compensated by good specificity and high positive predictive value as compared to other available methods. In other words, when the dog does detect something, it is almost always worthwhile to delve deeper.

References

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