THE EFFECTS OF EVAPORATING ESSENTIAL OILS ON INDOOR AIR QUALITY

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ABSTRACT

Our study aimed to examine the characteristics and concentrations of emitted VOCs when evaporating essential oils indoors. Three popular essential oils in the market, lavender, eucalyptus, and tea tree, based on a nation-wide questionnaire survey, were tested. Specific volatile organic compounds of interest were sampled and while evaporating the essential oils and analyzed by GC-MS. Indoor CO, CO$_2$, TVOCs, and PM$_{10}$ were measured using continuous monitors and duplicate airborne fungi and bacteria were collected in different periods of the evaporation.

Indoor CO, CO$_2$, and TVOCs levels have increased significantly after burning essential oils while PM$_{10}$ concentrations showed an opposite trend. The effects of anti-microbial activity on airborne microbes could only be found at the first 30 to 60 min when the highest levels of volatile components of these essential oils emitting into the air. Their effects on airborne microbes did not seem to persist through time.

INDEX TERMS

essential oil, TVOCs, CO, CO$_2$, PM$_{10}$, airborne fungi, airborne bacteria

INTRODUCTION

Essential oils are products extracted from different parts of plants, such as flower, stem and leaves, and generally of rather complex compositions either originally from the plants or modified during the preparation process (Bruneton, 1995). Essential oils are also considered as a mixture of various aromatic chemicals while aromatherapy is a branch of complementary medicine developed based on the historical experience of using essential oils (Healy, 1998), by administration through inhalations, oral intake, transdermal absorption, or as gargles and mouthwashes (Evans, 1998).

Essential oils and some fragrance extracted from them are widely adopted into modern society for they have been reported, at least in commercial setting, to produce a pleasant odor and generate bioactivities beneficial to human health, with only a few scientific studies elucidating the specific effects and their corresponding mechanisms (Lahlou, 2004). Meanwhile, it is only natural that use of essential oils and products containing fragrances will release mixed volatile organic compounds (VOCs) into the indoor air, and many of these, such as terpenes, and D-limonene have shown to play a role in the formation of second organic aerosols, often more irritating or allergenic than the original substance, after oxidation (Wainman, 2000). Therefore, increasing usage and exposure to essential oils and aromatic compounds have caused concerns for their potential health and environmental impacts in recent time.

Our preliminary data of investigating the habits of using essential oils in domestic environments have shown that above 20% of homes in Taiwan have the habits of using essential oils. Among them, more than 80% in average, evaporating is the most common way to apply essential oils in their daily life. Our study therefore conducted measurements in typical office space and residence to characterize and determine the effects of evaporating oils in indoor air quality.

RESEARCH METHODS

A questionnaire survey was first conducted to investigate market shares of different essential oils in the department stores to identify the most sold essential oils in Taiwan. Lavender (Lavandula angustifolis), eucalyptus (Eucalyptus globules), and tea tree (Melaleuca alternifolia) essential oils ranked the top 3,
comprising more than 50% of total sale volume. Bulk samples of these essential oils were analyzed by GC-MS to characterize the chemical compositions, and 300μl of each essential oil were diluted with 50 ml water for use in incense evaporator with burning candle. Two different types of indoor environments, 1 bedroom (space volume: 21.6m$^3$; air change rate (ACH): 1.8 hr$^{-1}$) and 1 small office (space volume: 28.2m$^3$; ACH: 1.3 hr$^{-1}$) were chosen for study. Before evaporating, 30 min background sampling was conducted to measuring background levels of various indoor air pollutants using continuous monitor and airborne microbial particulates were also collected before evaporating test. Monitoring of evaporating essential oils would begin after indicators of background environments were established, and the measurements were recorded for 3 continuous hours for each test. Triplicate tests were conducted for each kind of essential oil. Typical indoor air indicators including CO, CO$_2$, TVOCs, and PM$_{10}$ were measured using continuous monitors during the whole experimental process. Duplicate samples of airborne fungi and bacteria were collected using Burkard sampler (Rickmansworth, UK) with Malt Extract Agar plates (MEA) and Tryptic Soy Agar (TSA) at a flow rate of 10 LPM (Macher et al. 1995; Su et al. 2001). Airborne fungi and bacteria were collected on 0, 30, 60, 120, and 180 minutes within the period of evaporating essential oils. Ironless steel tubes filled with Tanex- TA and Carboxen for absorbing VOCs (EPA-TO-17) was equipped with a sample pump (SKC 223-3, U.S.A.) and sampling at flow rate of 70ml/min during the period of evaporating each essential oils in the testing space for volatile organic compounds sampling. Specific volatile organic compounds including Linalool, d-limonene, Terpinene-4-ol, Eucalyptol, and p-Cymene was thermally extracted, analyzed, and quantified by standard curve using GC-MS set at the identical condition as for bulk sample analysis.

**RESULTS**

![Figure 1](image-url)

**Figure 1.** The effects of evaporating essential oils on the indoor TVOC concentrations in the testing spaces (a. home and b. office)

The effects of evaporating essential oils on the indoor TVOC concentrations in the testing spaces were shown on Figure 1. The distribution patterns of TVOC levels demonstrate different emission patterns when evaporating various essential oils. Eucalyptus oil appeared to contain more volatile organic compounds than tea tree and lavender oils with highest levels of 2.952 ppm at the 12 min in home and 1.586 ppm at the 14 min in office space.
Moreover, the emissions of volatile organic compounds mostly occurred during the first 20 min of starting to evaporate essential oil of eucalyptus and tea tree oil, both at home and office environment. The emissions of volatile organic compounds of lavender oil seemed to be slower than eucalyptus and tea tree oils; yet, it also reached steady state within 30 to 45 min, again, either at home or office space.

The main constituents of lavender oil were linalool (23%) and linalyl arthranilate (40%). Eucalyptol (80%), D-Limonene (8%), and ρ-Cymene (5%) were major compositions in eucalyptus oils, and ρ-Cymene (12%), γ-Terpinene (18%), and Terpinene-4-ol-1 (43%) were in tea tree oils. Table 1 shows the levels of indicative volatile organic compounds during the testing periods. The level of linalool, major composition of lavender oils, was 496.04 to 986.90 μg/m³ when evaporating lavender oils in the testing space. D-limonene was found in all three essential oils, and the air concentrations were 2.37 and 69.32 μg/m³ in testing office and home, respectively. Terpinene-4-ol, also found in three essential oils, had the highest levels when evaporating tea tree oils (467.68 to 954.18 μg/m³). Eucalyptol was a major compound in eucalyptus and tea tree oils and the higher levels could be found when evaporating eucalyptus oils (203.09 to 1540.62 μg/m³) in testing space. Although ρ-Cymene was significantly present both in eucalyptus and tea tree oils, higher levels were found when evaporating the latter (72.25 to 903.38).

The levels of carbon dioxide (CO2) and carbon monoxide (CO) were significantly increased in the testing period, compared to the background levels (non-parametric test, p<0.001), possibly due to the combustion activity of burning candle. The levels of PM10 were observed to have minor increases during the evaporating test, yet without statistical significance (p=0.053). Indoor total fungi and bacteria concentrations appeared to decrease after evaporating lavender and eucalyptus oils regardless of office or home environment, and the lowest levels could be observed at 30 or 60 minutes. The levels of indoor total fungi and bacteria raised again after 60 min without significantly difference from the background levels at 120 and 180 min. The same phenomena could also be observed in evaporating tea tree oils at home.

<table>
<thead>
<tr>
<th>Compounds (μg/m³)</th>
<th>Office</th>
<th>Home</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
<td>2nd</td>
</tr>
<tr>
<td>Lavender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linalool</td>
<td>533.48</td>
<td>496.04</td>
</tr>
<tr>
<td>D-limonene</td>
<td>11.82</td>
<td>5.58</td>
</tr>
<tr>
<td>Terpinene-4-ol</td>
<td>99.55</td>
<td>74.49</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eucalyptol</td>
<td>523.42</td>
<td>1540.62</td>
</tr>
<tr>
<td>D-limonene</td>
<td>69.32</td>
<td>35.69</td>
</tr>
<tr>
<td>ρ-Cymene</td>
<td>57.72</td>
<td>46.02</td>
</tr>
<tr>
<td>Terpinene-4-ol</td>
<td>70.86</td>
<td>77.36</td>
</tr>
<tr>
<td>Tea Tree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eucalyptol</td>
<td>93.97</td>
<td>97.41</td>
</tr>
<tr>
<td>D-limonene</td>
<td>22.74</td>
<td>19.31</td>
</tr>
<tr>
<td>ρ-Cymene</td>
<td>132.16</td>
<td>119.21</td>
</tr>
<tr>
<td>Terpinene-4-ol</td>
<td>881.67</td>
<td>903.38</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Our finding suggested that evaporating lavender, eucalyptus, and tea tree oils using incense evaporator with burning candle would significantly contribute to the increase levels of TVOC, CO, and CO₂ in typical residential and office environments. Most volatile organic compounds would emit into the air within 30 min during the evaporating process. Although those aromatic compounds present in the pure essential oils, including linalool, d-limonene, terpinene-4-ol, eucalyptol, and ρ-cymene, were also found in the atmospheric environments and general indoor environments, the levels have not been as high as those measured in the current investigation, believed to have emitted into the air after evaporating essential oils [Helmig et al., 1992; Strömwall, 1992;...
Wallace et al., 1991]. While the relating case reports and epidemiological studies regarding the effects of these aromatic compounds remain limited, they have been suggested to be the sensitization agents [Dharmagunawardena et al., 2002; Buckley et al., 2003] calling for further research.

Exposure to fragrance and essential oils from the air has also induced or worsened respiratory problems including decrease of pulmonary function and increase of chest tightness, wheezing and exacerbates asthma in susceptible subjects [Kumar et al. 1995; Millqvist et al. 1999; Millqvist and Lowhagen 1996; Galdi et al., 2004]. In addition, fragrances are also accounted for the cause to occupational asthma [Baur et al. 1999; Lessenger 2001]. Respiratory symptoms and other nonspecific symptoms in susceptible subjects can be triggered by exposure via airway and other sensory pathway [Millqvist et al. 1999], and many of them are similar to those described in multiple chemical sensitivity and sick building syndromes [Millqvist et al. 1999; Opiekun et al. 2003]. The frequency of allergic reactions to d-limonene containing oxidation products is comparable to that of common allergens such as formaldehyde [Karlberg 1998]. Research has shown that prolong inhalation of Limonene and Carvone may affect both autonomic nervous system (ANS) and emotional status [Heuberger, 2001]. Animal model study also demonstrates that the motility of mice inhaling Linalool (major composition of lavender oils) decreases 40% [Jirovetz et al. 1991]. Our investigation has illustrated the air concentration of specific aromatic compounds when using evaporating essential oils at home and office environments, and warranted the need for further evaluation on their health implications.

Anti-microbial activities of essential oils have been documented for various essential oils, such as thyme, lavender, tea tree, and eucalyptus [Viljoen, 2003; Lis-Balchin et al., 1999; Hammer et al., 1999; Inouye et al., 2001; Pattnaik et al. 1997]. Our results indicated that the effects of anti-microbial activity on airborne microbes could only be found at the first 30 to 60 min when the highest levels of volatile components of these essential oils emitting into the air. Their effects on airborne microbes did not seem to persist through time.

CONCLUSION AND IMPLICATIONS

Our study first demonstrates the effects of evaporating essential oils with burning candles, a common way of applying essential oils in our population, on indoor typical pollutants and the levels of specific fragrance compounds during the evaporating process. It is apparent that increasing levels of indoor CO₂ and CO are likely to be a concern when adopting such a application method.

Furthermore, the fact that anti-microbial activity by evaporating lavender, tea tree, and eucalyptus oils could only be found at the first 30 to 60 min when the highest levels of volatile components of these essential oils emitting into the air. Their effects on airborne microbes did not seem to persist through time.

Although implications seem to remain inconclusive regarding the health effects of using essential oils as much toxicological and epidemiological evidence is extremely scarce, studies have continued to advocate their potential hazards, especially to susceptible subjects. Based on current finding, it may be recommended that occupants should refrain themselves from staying inside the enclosed space during the first 30 min when the combustion and emission process take place. Proper ventilation afterwards can be a way of prolonging the beneficial effects of evaporating essential oils.

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REFERENCES

Evans WC. 1998 “Trease and Evans’ Pharmacognosy.”, WB Saunders, UK  
Karlberg 1998.  
Kumar et al. 1995; Millqvist et al. 1999; Millqvist and Lowhagen 1996; Galdi et al., 2004.  
Kumar et al. 1995; Millqvist et al. 1999; Millqvist and Lowhagen 1996; Galdi et al., 2004.  
Karlberg 1998.  


