Relationship between indoor air chemical exposure and adverse health effects in a multiple chemical sensitivity suspected patient: a case report study

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Abstract

This paper reports a case study about the relationship between the symptoms of multiple chemical sensitivity (MCS) and indoor air chemicals. In April 2014, a 40-year-old man visited the Environmental Medical Clinic, Chiba University, claiming repeated symptoms of MCS after purchasing an electronic piano. Samples of indoor air from the living room of the patient’s house were collected and chemicals were analysed eight times – when an electronic piano and toys for children were either present or absent, and the floor heating system was on and off. Indoor air in a university office, and outdoor air were used as controls. As a result, it was found that the concentrations of 13 VOCs, for which the Ministry of Health Labour and Welfare of Japan (MHLW) set guideline values, were lower than the guideline values in all the samples. The total volatile organic compounds (TVOC) in three indoor air samples collected from the patient’s house were 550, 520, and 460 μg/m³; slightly higher than the target value (400 μg/m³) of TVOC set by the MHLW. The patient claimed to have the symptoms in all three cases. Furthermore, symptoms were reduced or eliminated when ventilation was conducted, or the patient was exposed to the outdoor air. A tendency was found that symptoms were strengthened as TVOC increased. In conclusion, MCS symptoms in this case were related to indoor air quality, and symptoms appeared even when the 13 VOCs for which the guideline values are set were lower than the guideline values. Therefore, it can be said that TVOC could be used as an indicator of the effects of indoor air quality on human health.
Keywords: indoor air chemical exposure, adverse health effects, indoor air quality, multiple chemical sensitivity, total of volatile organic compounds.

1 Introduction

Multiple chemical sensitivity (MCS) is a syndrome with a series of symptoms linked to low level multiple chemicals exposures. It has been described under various names such as Chemical Injury or Environmental Illness since the 1940s. Cullen [1] determined MCS in 1987 as an acquired disorder characterized by recurrent symptoms referable to multiple organ systems, occurring in response to demonstrable exposure to many chemically unrelated compounds at doses far below those established in the general population to cause harmful effects. Since then, several theories have been advanced to explain the cause-effect relationship of MCS. However, there is insufficient scientific evidence to confirm it. MCS symptoms which have been reported are wide-ranging and they vary tremendously from one patient to another. Furthermore, there is a debate that whether MCS is a disorder mediated by psychiatric factors such as anxiety, depression or genuine physical susceptibility to low dose exposure to chemicals (Fiedler and Kipen [2]; Kipen and Fiedler [3]).

In April 2014, a 40-year-old medical doctor of psychiatry visited our Environmental Medical Clinic of the Center for Preventive Medical Sciences, Chiba University for advice about repeated symptoms of MCS after purchasing an electronic piano (Fig. 1). This paper reports as a case study, the identification of the relationship between the co-occurrence of symptoms and indoor air chemical exposure.

Figure 1: Left: indoor air sampling in the patient’s living room by active sampling method; upper right: living room, where the electronic piano, clay toys, game cards, and a book for children were kept inside; bottom right: outdoor air sampling by active sampling method.
2 Materials and methods

To investigate the relationship between the occurrence of symptoms and indoor air chemicals, the indoor air samples were collected and chemicals in the air samples were analysed. During the sampling, the subject who suspected MCS, stayed in the room and answered a questionnaire about his symptoms. The subject is a medical doctor of psychiatry who doesn’t have psychiatric disorders.

2.1 Indoor air sampling and analysis

Indoor air in the living room of the subject’s house was collected eight times under the following conditions.

1. The electronic piano was taken away.
2. The electronic piano was kept inside.
3. After 30 minutes of ventilation by opening the windows, while the electric piano was kept inside.
4. The floor heating system was on and the electronic piano was kept inside.
5. The electronic piano, clay toys, game cards, and a book for children were kept inside.
6. The air conditioner and humidifier were on and the electronic piano was kept inside.

As controls, the indoor air of a university office and outdoor air were collected, and the subject did not show any symptoms during the sampling.

2.2 Analysis of indoor air

In this study, 86 volatile organic compounds (VOCs) in the air samples were analysed. Measurement methods were performed in reference to “the standard methods of air sampling and measurement” issued by the MHLW [4]. Air samples were collected by active sampling method for 30 minutes by using Tenax® TA (Supelco, Sigma Aldrich, USA) to capture VOCs, and LpDNPH S10L (Supelco, Sigma Aldrich, USA) to capture aldehydes. The air was passed through the Tenax® TA sampler and DNPH sampler at flow rates of 100 ml/minute and 1000 ml/minute, respectively. The collected VOC were extracted by using thermal desorption and analysed by using gas chromatography-mass spectrometry (GC/MS). For the aldehyde analyses, solvent extraction and high-performance liquid chromatography (HPLC) were used. Thermal desorption of the Tenax® TA was carried out by using a Turbo Matrix ATD (PerkinElmer, Waltham, MA USA). The analysis of VOCs was performed by using an Agilent
890 and 5973 N (Agilent Technologies Inc., CA USA) in SCAN mode (m/z 43-400). The analysis of aldehydes was performed by using an LC-20A HPLC system (Shimadzu Co., Kyoto, Japan) with detection at 365 nm. A 150 mm × 4.6 mm i.d. Ascentis RP-Amide column with 3.0 μm particle size was used at 40°C. The flow rate was 1 ml/minute and the mobile phase was 40–80% acetonitrile in water, with gradient elution mode for 60 min. The limit of quantification for each of the chemicals was 1.0 μg/m³, except for acetic acid (4.0 μg/m³). In this study, TVOC was defined as the sum of the concentration levels of all compounds found with retention times between hexane and n-hexadecane determined by using the response factor of toluene. During sampling, indoor air conditions (e.g., temperature and humidity) were recorded.

2.3 Evaluation by human sensory perception

Before the evaluation of indoor air quality by the subject, the procedure was explained and an informed consent was obtained. Following which, he answered the Quick Environmental Exposure and Sensitivity Inventory (QEESI®, which is a screening instrument for MCS (Miller and Prihoda [5, 6]). The questionnaires are to ask about the symptoms precisely and evaluate the strengths. The odour query was scored from ‘0’ to ‘5’ (0: odourless; 1: slight odour; 2: weak odour; 3: distinct odour; 4: strong odour; 5: poignant odour).

2.4 Medical research ethics

This study was approved under approval No. 1850 by the Research Ethics Committee of the Graduate School of Medicine, Chiba University. Informed consent also was obtained from the subject.

3 Results

The MHLW of Japan set non-binding guideline values for 13 VOCs, and an interim target value for total VOCs (TVOC) at 400 μg/m³ (MHLW [7]). Table 1 shows that the concentrations of 13 VOCs for which MHLW set guideline values, were lower than the guideline values in all the samples. The concentrations of aldehydes, TVOC, and temperature in each situation are shown in Fig. 2. The TVOC concentrations varied from 37 to 550 μg/m³. The TVOCs in three samples were 550, 520, and 460 μg/m³ respectively, which were slightly higher than the TVOC target value set by the MHLW, when the floor heating was on, and the electronic piano, clay toys, and game cards all were present in the living room.
Table 1: Comparison of VOC concentrations with 13 VOC guidelines.

<table>
<thead>
<tr>
<th>VOC</th>
<th>Guideline values</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
<th>S8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetradecane</td>
<td>330</td>
<td>1.3</td>
<td>1.2</td>
<td>ND</td>
<td>1.1</td>
<td>1.2</td>
<td>1.4</td>
<td>1.6</td>
<td>ND</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>3,800</td>
<td>1.2</td>
<td>3.2</td>
<td>6.2</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.8</td>
<td>ND</td>
</tr>
<tr>
<td>Styrene</td>
<td>220</td>
<td>1.1</td>
<td>8.7</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>1.1</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Toluene</td>
<td>260</td>
<td>7.3</td>
<td>11</td>
<td>31</td>
<td>5.3</td>
<td>5.3</td>
<td>8.6</td>
<td>3.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Xylene</td>
<td>870</td>
<td>1.3</td>
<td>2.1</td>
<td>7.3</td>
<td>1.7</td>
<td>1.6</td>
<td>1.5</td>
<td>7.3</td>
<td>ND</td>
</tr>
<tr>
<td>p–Dichlorobenzene</td>
<td>240</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>2.1</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>100</td>
<td>31</td>
<td>39</td>
<td>20</td>
<td>40</td>
<td>44</td>
<td>74</td>
<td>29.8</td>
<td>3.2</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>48</td>
<td>13</td>
<td>30</td>
<td>9.4</td>
<td>14</td>
<td>23</td>
<td>21</td>
<td>17</td>
<td>2.5</td>
</tr>
<tr>
<td>Di–2–ethylhexyl phthalate DEHP</td>
<td>120</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.2</td>
<td>–</td>
</tr>
<tr>
<td>Dibutylphthalate</td>
<td>220</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.7</td>
<td>–</td>
</tr>
<tr>
<td>Diazinon</td>
<td>0.29</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>ND</td>
<td>–</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>1</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>ND</td>
<td>–</td>
</tr>
<tr>
<td>Fenobcarb</td>
<td>33</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>ND</td>
<td>–</td>
</tr>
<tr>
<td>TVOC</td>
<td>400</td>
<td>330</td>
<td>550</td>
<td>220</td>
<td>520</td>
<td>460</td>
<td>390</td>
<td>100</td>
<td>37</td>
</tr>
</tbody>
</table>

Unit = µg/m³, aSource of guidelines = Ministry of Health, Labor, and Welfare of Japan.
ND = not detected,   - (hyphen) = not conducted,   S = situation.
S2. With EP.
S3. After 30 min of ventilation by opening the windows, with EP.
S4. Floor heating system was on, with EP.
S5. EP plus clay toys, game cards and a book for children were kept.
S6. Air conditioner and humidifier were on, with EP.
S7. University office.
S8. Outdoor air.
3.1 Relationship between indoor air chemicals and symptoms

According to the QEESI score, the patient was suspected of being highly sensitive to chemicals. The criterion for judging sensitivity follows the one in the

<table>
<thead>
<tr>
<th>Site</th>
<th>Situation</th>
<th>Symptoms</th>
<th>Strength of symptoms</th>
<th>Odour</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Without EP(^a)</td>
<td>Symptoms not noted</td>
<td>Tolerable</td>
<td>0</td>
</tr>
<tr>
<td>S2</td>
<td>With EP</td>
<td>Shoulder pain, eye pain</td>
<td>Tolerable for 30 min</td>
<td>0</td>
</tr>
<tr>
<td>S3</td>
<td>Ventilation, with EP</td>
<td>Symptoms not noted</td>
<td>Tolerable for 30 min</td>
<td>0</td>
</tr>
<tr>
<td>S4</td>
<td>Floor heating on, with EP</td>
<td>Heavy-headed, nausea, cognitive decline</td>
<td>Intolerable longer than 5 min</td>
<td>0</td>
</tr>
<tr>
<td>S5</td>
<td>Floor heating, on, with EP, clay toys, game cards, a book</td>
<td>Heavy-headed, nausea, cognitive decline</td>
<td>Intolerable longer than 5 min</td>
<td>0</td>
</tr>
<tr>
<td>S6</td>
<td>Air conditioner on, with EP</td>
<td>Heavy-headed, nausea, cognitive decline</td>
<td>Mild, tolerable for 10 min</td>
<td>0</td>
</tr>
<tr>
<td>S7</td>
<td>University office</td>
<td>No symptoms</td>
<td>Does not apply</td>
<td>0</td>
</tr>
<tr>
<td>S8</td>
<td>Outdoors</td>
<td>No symptoms</td>
<td>Does not apply</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^a\)EP = electronic piano.

Figure 2: Temperature and measures of TVOC and aldehyde concentration (x-axis unit = μg/m\(^3\)) in each situation.
study by Hojo et al. [8, 9]. The patient claimed the most severe symptoms when the TVOC value was higher than the guideline target value. It was unbearable for him to stay in the living room longer than 5 min when the electric piano was kept inside, and the heating system was on. In this situation, he even claimed a decline of ability to think. On the other hand, symptoms were reduced or eliminated when the subject was in the university office, after the air was ventilated, or when subject was exposed to outdoor air. A tendency was found that the symptoms were strengthened as the TVOC increased.

4 Discussion and conclusions

In this study, 86 VOCs in indoor air were measured and analysed in eight situations. In each situation, the subject stayed inside and answered questions related to the symptoms. The results show that the symptoms appeared even if the 13 VOCs for which the guidelines were set were low, and if the TVOC value was lower than the target value. However, there was a tendency that the symptoms were strengthened as the TVOC value increased. According to our previous study, it was found that TVOC values were significantly correlated with sick building syndrome (SBS) symptoms, especially among the sensitive group when the concentration level of TVOCs was greater than about 400 μg/m³ (Nakaoka et al. [10, 11]). Also in this study, it became clear that people who were physical susceptible to chemicals tend to react to low dose exposure to chemicals. In conclusion, the MCS symptoms in this case were related to indoor air quality, and TVOC could be used as an indicator of the effects of indoor air quality on human health.

We are going to continue this study to investigate the causes of the occurrence of MCS symptoms precisely through the emission test of electronic piano, clay toys, playing cards and so on.

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