

Prevalence of Plastic Additives in Indoor Air related to Newly Diagnosed Asthma

K. Villberg^a H. Mussalo-Rauhamaa^b T. Haahtela^c
K. Saarela^d

^aHalton Oy, Niittyvillankuja 4, FI-01510 Vantaa, Finland

^bState Provincial Office of Southern Finland, PO Box 110, FI-00521 Helsinki, Finland

^cSkin and Allergy Hospital, Helsinki University of Central Hospital, PO Box 160, FI-00029 HUCH, Helsinki, Finland

^dVTT Technical Research Centre of Finland, PO Box 1000, FI-02044 VTT, Finland

Key Words

2,2,4-trimethyl-1 · 3-pentanediol di-isobutyrate · plastic additive · indoor air · newly diagnosed asthma

(2,2,4-trimethyl-1, 3-pentanediol di-isobutyrate) was $10\mu\text{g}/\text{m}^3$ or greater (in Toluene equivalent), the age and sex adjusted odds ratio of having new asthma was 2.844, 95% CI 1.035–7.813.

Abstract

This paper presents a correlation between the certain plastic additives and newly diagnosed asthma. We studied this association by measuring the plastic additives in the indoor air of the homes of presenting patients at the Skin and Allergy hospitals, including old and new, clinically diagnosed cases of asthma and controls. A total of 465 people filled in a questionnaire that probed, for example, health complaints, illnesses, and perceived conditions of their home environment. Asthma was diagnosed in 19 patients, and had earlier been found in 31 people. Compounds commonly used in plastic flooring manufacture were found to be more prevalent and in higher concentrations in the homes of subjects having newly diagnosed asthma. When the indoor air concentration of one plastic additive

Introduction

Good indoor air quality has a notable impact on human health and comfort. Nevertheless, a healthy indoor climate is not always obvious, but it should be accessible. Indoor air is strongly affected by the surrounding building materials releasing a wide variety of chemical compounds, which are suggested to cause several types of health effects and discomfort. This is one very important reason for seeking an answer to the question: “What kind of relationship exists between VOCs and health effects?” A wide range of different symptoms is usually reported when building-related problems are questioned. Principally, the most common symptoms are nose symptoms, eye symptoms, and throat symptoms. Many reports

have shown that the prevalence of childhood asthma and symptoms suggestive of asthma has risen, and the degree of this varies in different countries [1–5]. Some correlation has been reported between asthma and various different factors, e.g., sensitivity to airborne moulds and severity of asthma [6,7]. However, there is still no clear reason for the increase in asthma. In Finland the prevalence of asthma had been fairly constant since the 1960s [8]. However, this substantially increased between 1982 and 1992. In the same time period the use of plastic flooring materials widely increased, especially in Europe. It has also been shown that the synthetic chemicals commonly used in plastic materials widely used in consumer goods appear to increase a person's risk of developing allergies and asthma [6,9–12]. Wieslander et al. found an increased prevalence of asthma among subjects with domestic exposure to newly painted surfaces, particularly where levels of 2,2,4-trimethyl-1,3-pentanediol di-isobutyrate and aliphatic compounds were raised [11]. Studies of Metiäinen et al. showed that there was an association between this compound and residents' symptoms [13,14]. They also found that when the flats with a high content of 2,2,4-trimethyl-1,3-pentanediol di-isobutyrate were repaired, i.e., old PVC – carpets and glue were removed and room temperature and ventilation rate were increased for a couple of weeks while a new low-emitting M1-labeled

PVC – carpet was glued on the floor the concentrations of 2,2,4-trimethyl-1,3-pentanediol di-isobutyrate decreased dramatically. From one to six months after repair 74% of the residents reported significant or slight decrease in their symptoms.

In our earlier study it was shown that a high level ($20 \mu\text{g}/\text{m}^3$ or greater in Toluene equivalent) of this compound in indoor air seemed to increase the risk of symptoms like nose and, especially, eye irritation (OR 16.4069 95% CI 3.539–76.0483) [15].

Study Subjects and Methods

Study Design

We conducted a cross-sectional study based on hospital patients and their families, and randomly selected control families to investigate the indoor air quality at their homes, and its association with newly diagnosed asthma (Figure 1). This study was part of the *Finnish Research Programme on Environmental Health* (SYTTY) and was aimed at establishing measurable criteria for healthy and comfortable indoor air and finding the connection between indoor air quality, perceived comfort and diagnosed health effects.

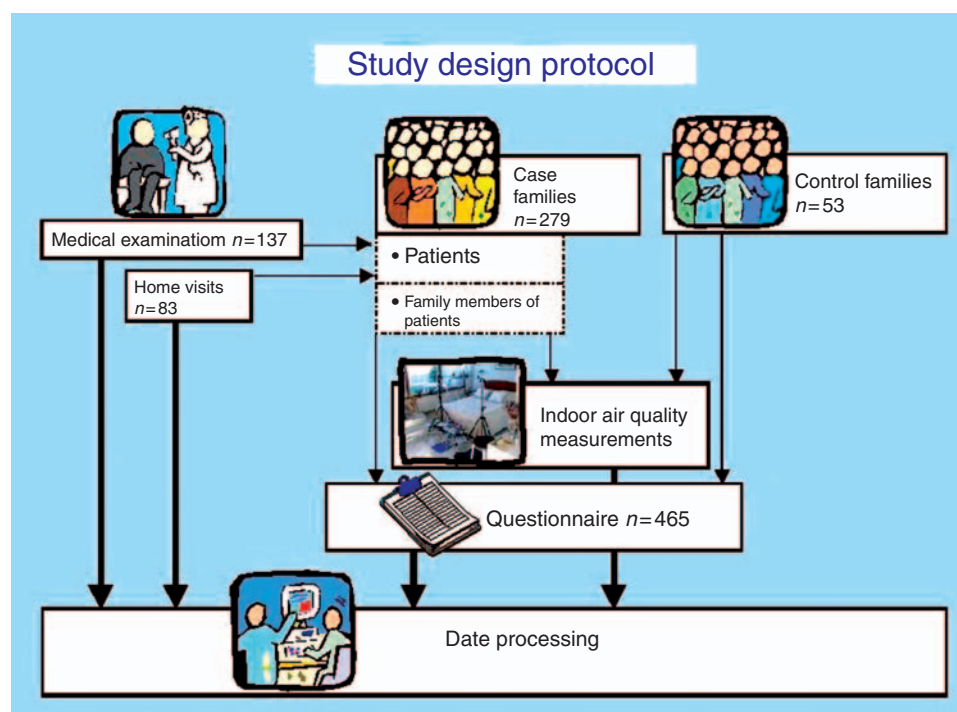


Fig. 1. Study design protocol.

Subjects

A total of 137 patients were selected from the patients of the Helsinki University Central Hospital, Skin and Allergy Hospital. They were examined by the staff physicians, mainly Dr H. Mussalo-Rauhamaa (one of the authors). The medical examination comprised, e.g., clinical status, pulmonary function tests and skin prick tests for common allergens. Clinical data were only collected from those patients undergoing the medical examination.

The patients and their family members, in addition to the members of 30 control families (a total of 53 people), filled in a modified Örebro (MM-40-FIN) [16] and Tuohilampi questionnaire [17] probing, e.g., health complaints, illnesses, and perceived conditions of the home environment. The questionnaire consisted of different parts: (1) Living environment, which characterises the house type where the subjects lived and the building/finishing materials used; (2) Profiling the subject, which posed such questions as sex, smoking habits, living habits; (3) Living-related symptoms, which describe the conditions experienced in their homes and various symptoms associated with living in their homes; and (4) Medical history of patients, which described previous and present illnesses and different allergies based on a diagnosis by a medical doctor. A total of 465 persons returned the questionnaire. Both questions about indoor climate factors and symptoms had three alternative answers; “yes, often (every week)”, “yes sometimes” and “no, never”. The persons were asked to report their symptoms during the last 3 months and illnesses during the last 12 months. Parents filled the questionnaire for their under 14-year-old children. The controls were randomly selected from the inhabitants of the Helsinki area who were living in similar types of houses as the patients.

Analytical Methods

The indoor air quality was measured with methods used today in the Finnish classification, but complementary new methods were also applied and tested for their relevance in attaining a better coverage of different chemical substances in indoor air. Indoor climate and quality measurements (volatile organic compounds (VOCs), ammonia and formaldehyde) were carried out in the homes of the patients and control subjects.

Statistics

All the data were statistically analyzed using the SPSS statistical package for Windows 9.0 (Chicago, Illinois, USA). We used the chi-square test to analyze the differences in subjective environmental factors and the

symptoms between the groups and the logistic regression models. Alpha levels of less than 0.05 were considered statistically significant; levels between 0.05 and 0.10 were considered to be of interest.

Ethics

The study was conducted in accordance with national and institutional guidelines for the protection on human subjects. The Ethics Committee of the Skin and Allergy Hospital approved the study protocol. All the patients gave their information consent.

Results

Reasons for the hospital admission of patients in different age groups are given in Table 1. The most common reason for hospital admission was cough in children under 15-years of age and nose symptoms in males and females. Based on the questionnaire the most frequently reported symptoms were stuffy air and unpleasant odor at home and for their symptoms those related to the nose (irritation/rhinitis, stuffy nose, sinusitis, and phlegm), eye, throat (headache, eczema, asthma, hoarseness, dyspnea, and cough) and mucous membranes. The control families had very few symptoms or none at all. Thus, the control selection obviously succeeded.

Using the statistical correlations, the dominant chemical groups were detected for the cases with the above-mentioned symptoms. Concerning the odor-dependant symptoms, such as stuffy air and unpleasant odor, the obvious chemical groups were basically carbonyl compounds (aldehydes, ketones, and carboxylic acids), which are well-known odorous compounds. In addition, some aromatic compounds present were partly responsible for the odor. The most common compound correlating with a wide range of symptoms was 2-ethyl-1-hexanol, which was connected to the nose symptoms (in every listed case), throat symptoms and mucous membrane symptoms. Another compound was 2,2,4-trimethyl,1,3-pentanediol di-isobutyrate, which correlated significantly with the nose symptoms and eye symptoms. Different chemical groups, like terpenes, carbonyl compounds, aromatics, and specific material-based compounds, were dominant in the homes investigated. Low rates of ventilation and air exchange seem to exacerbate the effects of the indoor air pollutants.

Asthma was diagnosed in 19 patients, and had earlier been found in 31 people. Asthma diagnosis was based on symptoms appropriate for asthma and establishing variable airway obstruction, e.g., nonsymptomatic baseline

Table 1. Reasons for hospital admission

Reason for examination symptoms/illnesses/other causes	Children/boys <15-v	Children/girls <15-v	Male >14-v	Female >14-v	Total
Skin symptoms	3 (11.5%)	4 (10.0%)	2 (6.3%)	11 (18.9%)	20 (14.8%)
Dyspnea	7 (26.9%)	2 (10.0%)	6 (18.8%)	17 (29.3%)	32 (23.7%)
Sinusitis	—	2 (10.0%)	2 (6.3%)	2 (3.4%)	6 (4.4%)
Cough	8 (30.8%)	4 (20.0%)	5 (15.6%)	7 (12.1%)	24 (17.8%)
Nose symptoms	—	3 (15.0%)	9 (28.1%)	12 (20.7%)	24 (17.8%)
Eye symptoms	—	—	2 (6.3%)	2 (3.4%)	4 (3.0%)
Sore throat	—	—	2 (6.3%)	—	2 (1.5%)
Infections	2 (7.7%)	1 (5.0%)	—	1 (1.7%)	4 (3.0%)
Dizziness	—	—	—	1 (1.7%)	1 (0.7%)
Allergic symptoms	2 (7.7%)	3 (15.0%)	1 (3.2%)	—	6 (4.4%)
Suspicion of indoor air problem	—	—	—	1 (1.7%)	1 (0.7%)
Hives	—	—	—	1 (1.7%)	1 (0.7%)
Asthma control	2 (7.7%)	—	—	2 (3.4%)	4 (3.0%)
Articular disease	1 (3.8%)	—	—	1 (1.7%)	2 (1.5%)
Headache	1 (3.8%)	—	—	—	2 (0.7%)
Edema	—	—	1 (3.2%)	—	1 (0.7%)
Other	—	—	1 (3.2%)	1 (1.7%)	2 (1.5%)
Total	26 (100%)	20 (100%)	32 (100%)	59 (100%)	137 (100%)

Table 2. 2,2,4-trimethyl-1,3-pentanediol di-isobutyrate concentration in indoor air $\mu\text{g}/\text{m}^3$

ASTHMA TYPE*	Mean	N	Std. deviation	Median	Minimum	Maximum	Geometric mean
Old diagnosed asthma	5.09	21	5.09	3.83	0.83	20.10	3.37
Newly diagnosed asthma ($p=0.01$)	15.90	19	19.12	5.67	1.77	77.59	8.93
Other illness	11.37	196	19.42	3.55	0.58	77.59	4.47
Total	11.18	236	18.67	3.83	0.58	77.59	4.61

*diagnosed by a medical doctor, not a self-reported symptom.

obstruction improving after inhaled beta2 agonist and with peak expiratory flow (PEF) or PEV_1 improving >15%: the criteria reported by NHLBI/WHO [18]. Compounds commonly used in plastic flooring manufacture were found to be more prevalent and in higher concentrations in the homes of subjects having newly diagnosed asthma, Table 2. When the indoor air concentration of a plastic additive was $10 \mu\text{g}/\text{m}^3$ or greater (in Toluene equivalent), the age and sex adjusted odds ratio of having new asthma was 2.844, 95% CI 1.035–7.813. Figure 2 shows the 2,2,4-trimethyl-1,3-pentanediol di-isobutyrate concentration in indoor air and occurrence of weekly reported symptoms like nose, eye, and throat irritation in people who were exposed in their homes to concentrations of the chemical from <10 to $>30 \mu\text{g}/\text{m}^3$.

Discussion

It is noteworthy that the prevalence of asthma has increased in Finland during the same period that plastic

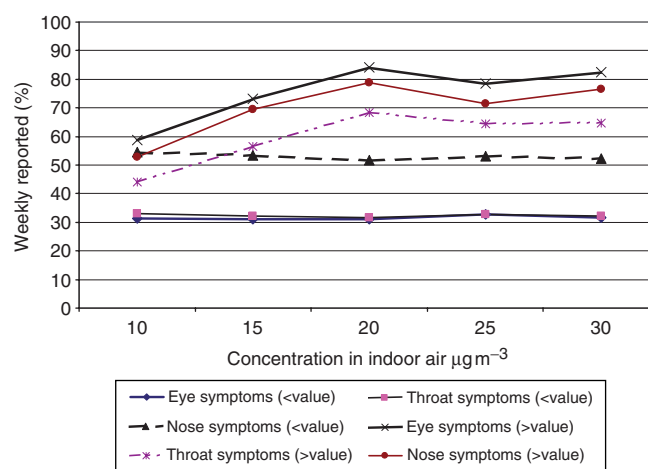


Fig. 2. Prevalence of symptoms after exposure to concentrations of 10, 15, 20, 25, and $30 \mu\text{g}$ -2,2,4-trimethyl-1,3-pentanediol di-isobutyrate/ m^3 . At each concentration point, the occurrence of symptoms in people are shown separately for those exposed to less than (<value) the value (e.g., $10 \mu\text{g}\cdot\text{m}^{-3}$) and in those exposed to over (>value) the value (e.g., $10 \mu\text{g}\cdot\text{m}^{-3}$). Based on the lines drawn, the maximum increase of eye, nose, and throat symptoms seems to be reached at the level of $20 \mu\text{g}\cdot\text{m}^{-3}$.

additives were increasingly used in flooring materials. This may be a direct effect of plastic additive exposure or such compounds may be acting as a marker for another component. The compound 2,2,4-trimethyl-1,3-pentanediol di-isobutyrate is widely used in the production of PVC-based vinyl floor coverings and other vinyl products. Flooring manufacturers have stated that release of this compound should be minimal in the normal domestic environment. The compound itself has not been found to be irritant to human beings. This has been reinforced by recently published work which notes this plastic additive did not contribute to sensory irritation *per se* [19]. However, the widespread use of flooring materials containing this compound and the results of our study

may indicate that 2,2,4-trimethyl-1,3-pentanediol di-isobutyrate is a compound of major public health importance.

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