Olfactory loss in poly (acrylonitrile-butadiene-styrene) plastic injection-moulding workers

Shu-Fang Cheng¹,², Mei-Lien Chen¹, Po-Chen Hung², Chiou-Jong Chen² and I-Fang Mao¹

Background
Plastics manufacturing factories are the fifth largest category of factories in industrial estates in Taiwan. It is known that complex airborne compounds and pungent odours are emitted during plastic injection-moulding processes. Workers exposed to acrylonitrile-butadiene-styrene (ABS) thermal decomposition products (TDP) may have olfactory loss.

Aims
This study examined olfactory loss in injection-moulding workers exposed to ABS TDP.

Methods
The method recommended by the Connecticut Chemosensory Clinical Research Center (CCCRC) was used to test the olfactory function of subjects, including 1-butanol threshold and odour identification, both pre- and post-work. The study sample included 52 ABS plastic injection-moulding workers (exposed group), as well as 72 workers from other departments (reference group).

Results
The results revealed that the exposed group had lower olfactory function after work than the reference group. The decrease in olfactory function after 1 workday was statistically significant. The prevalence of abnormal olfactory function post-work in the exposed group was higher than in the reference group.

Conclusions
The findings of this study implied the ABS plastic injection-moulding process may worsen olfactory function among workers. Notably, this effect decreased olfactory threshold scores, not odour identification scores.

Key words
1-Butanol threshold test; odour identification test; olfactory function; plastic injection-moulding process.

Introduction
Plastic components are essential in appliances, automobiles, toys and countless other applications [1]. Plastic manufacturers mix multiple resins to achieve features such as resilience, resistance to corrosion and so on. Despite the fact that resin polymers in themselves are generally biologically inert, they can decompose during moulding. Complex airborne compounds are emitted during plastic injection-moulding processes, including monomers, additives and thermal decomposition products (TDP). Consequently, plastic manufacturing factories are characterized by pungent odours. Moreover, workers experience exposure to low concentration levels of several airway irritants [2–5].

From government statistics, plastics manufacturing factories are the fifth largest category of factories in industrial estates in Taiwan in terms of total numbers (representing ~7.5% of the total number of factories) [6]. This suggests that workers’ exposure to resin TDP is not...
an uncommon phenomenon. Taiwan is well known for its computer manufacturing industry. Computer cases are mainly made from acrylonitrile-butadiene-styrene (ABS) plastics, which combine the characteristics of the chemical resistance of acrylonitrile, the impact resistance of butadiene, and the rigidity and the gloss of styrene.

ABS plastics are generally subjected to relatively high temperatures during processing, often causing decomposition into gaseous and volatile compounds, as well as non-volatile residues. Types and levels of thermal decomposition compounds depend on degradation conditions, plastic composition and the analysis method employed [7]. Many of these compounds are potentially toxic, for example, styrene, toluene, ethylbenzene, acrolein, acrylonitrile, formaldehyde and other organic nitriles [2,7]. Several compounds of ABS TDP are respiratory irritants and can induce anatomical and physiological changes in the olfactory system, or olfactory loss [7,8]. Other studies have found TDP to have cumulative respiratory effects upon repeated exposure to ABS [9].

The olfactory receptor cells are the only neurones whose cell bodies directly contact the exterior environment and thus it is not surprising that olfactory function is vulnerable to impairment by certain chemical agents [10]. Olfactory chemosensory dysfunction is not as obvious to the observer as visual or aural dysfunction and nor does it have the same life-style implications. However, it can still substantially impair quality of life, impede performance in certain occupations (such as food preparation, perfumery), lead to nutritional difficulties, and thus it is not surprising that olfactory function to be determined both pre- and post-work, as well as revealing the change in olfactory function during a single workday.

Three universal methods can be used to test olfactory function, namely those developed by the Monell–Jefferson Chemosensory Clinical Research Center (MJCCRC), University of Pennsylvania (Upenn) Smell and Taste Center and CCCRC. The three methods produce closely correlating results [12]. Considering test time, economy and convenience, this study selected the CCCRC method for testing subjects’ olfactory function. This olfactory function test comprises two parts: 1-butanol threshold test for testing peripheral olfactory receptor cell function [13,14] and odour identification test involving seven items [14,15].

The composite score comprised the 1-butanol threshold score and the odour identification score [14]. The composite scores of both nostrils together and of individual nostrils are averaged using the threshold and identification scores.

Points were assigned according to threshold concentration detected and number of odours identified [13,15]. Diagnostic categories of olfactory function were allocated based on the sum of the above two points. Olfactory function was categorized as follows: anosmia (0–10 points); severe hyposmia (20–40 points); moderate

Materials and methods

One-hundred-and-forty subjects were randomly selected from four ABS plastics processing plants during 2001–2002. The four subject plants mainly manufactured computer shells and were medium in scale, with 80–130 employees, 25–35 injection-moulding machines, each having a mould-clamping force of 50–200 tons. Annual synthetic polymer consumption totaled 500–1000 tons and the heating temperature of the synthetic polymers was ~210–240°C. The factory buildings were designed to have a high ceiling (~6 m) to facilitate the movement of moulds or heavy bodies. The area of each plant was ~1500–2000 m² and each plant had a general ventilation system.

The subjects were sampled following the stratified sampling principle. First of all, we investigated the total number of exposed workers and reference workers in all four factories. Because the number of female ABS plastic injection-moulding workers was very small, we selected male workers as our subjects. There were in total 138 exposed and 207 reference male workers in the four factories. In each factory, we sampled ~40% of the exposed and reference male workers by simple random sampling.

The exposed group comprised male workers working in the injection-moulding area over 6 months. The reference group comprised male workers working in other departments over 6 months of the same plants. Work history investigation showed that some of the reference subjects had previously worked in the ABS TDP area and they were excluded. Workers suffering colds, congenital/acquired anosmia and chronic sinusitis, plus those who had experienced head trauma, cranial surgery, or had a family history of respiratory disease were excluded. The study was approved by the review board of the Department of Public Health at National Yang-Ming University, Taipei, Taiwan.

Subject olfactory function was tested pre- and post-work on a Thursday. This approach allowed olfactory function to be determined both pre- and post-work, as well as revealing the change in olfactory function during a single workday.

This study employs the olfactory function test recommended by the Connecticut Chemosensory Clinical Research Center (CCCRC), which comprises a 1-butanol threshold test and odour identification test, to examine olfactory function loss in ABS plastic injection-moulding workers.
hyposmia (50–60 points); mild hyposmia (70–80 points); and normosmia (90–100 points).

SAS statistical software, version 8.01, was used to complete the two-tailed \( t \)-test, paired \( t \)-test or \( \chi^2 \) test of the study data.

**Results**

The study conducted olfactory function tests on 52 workers in the exposed group and 72 workers in the reference group. No statistically significant differences existed between the two groups in terms of age, number of years of employment, height, weight, marital status, education, smoking, betel nut chewing and alcohol consumption (\( P > 0.05 \), shown in Table 1).

The pre-work olfactory scores were not found to be significantly lower in the exposed group than in the reference group. However, post-work threshold and composite scores were found to be significantly lower in the exposed group compared to the reference group (\( t \)-test, \( P < 0.001 \) for the threshold and composite scores shown in Table 2). The exposed group had significantly lower composite scores than the reference group following work in the right and left nostril (\( t \)-test, \( P < 0.01 \) for the right and left nostrils, shown in Figure 1).

The change in composite olfactory scores over one workday was found to be significantly reduced in the exposed subjects (paired \( t \)-test, \( P < 0.001 \)). Threshold scores were significantly reduced in the exposed workers (paired \( t \)-test, \( P < 0.001 \)), but the identification scores were not (paired \( t \)-test, \( P = 0.57 \), shown in Table 2). This significant reduction was shown in both the right and left nostril composite scores of individuals following one workday.

Regardless of whether or not subjects were exposed to ABS TDP, the mean composite score after 1 workday in smokers for both nostrils was lower than that of non-smokers.

<table>
<thead>
<tr>
<th>Table 1. Demographics of study participants (values are mean ± SD)</th>
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<tbody>
<tr>
<td>Exposed group (( n = 52 ))</td>
</tr>
<tr>
<td>Age in years(^a)</td>
</tr>
<tr>
<td>Years employed(^a)</td>
</tr>
<tr>
<td>Height(^a) (cm)</td>
</tr>
<tr>
<td>Weight(^a) (kg)</td>
</tr>
<tr>
<td>Marital status(^b) (no.)</td>
</tr>
<tr>
<td>Married</td>
</tr>
<tr>
<td>Unmarried</td>
</tr>
<tr>
<td>Education(^b) (no.)</td>
</tr>
<tr>
<td>Elementary school</td>
</tr>
<tr>
<td>Junior school</td>
</tr>
<tr>
<td>Senior school</td>
</tr>
<tr>
<td>Above</td>
</tr>
<tr>
<td>Smoking habit(^b) (no.)</td>
</tr>
<tr>
<td>Smokers</td>
</tr>
<tr>
<td>Non-smokers</td>
</tr>
<tr>
<td>Betel nut chewing habit(^b) (no.)</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Drinking habit(^b) (no.)</td>
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<tr>
<td>Yes</td>
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<tr>
<td>No</td>
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</tbody>
</table>

\(^a\)Student’s \( t \)-test: exposed group versus reference group.

\(^b\)\( \chi^2 \) test.

<table>
<thead>
<tr>
<th>Table 2. Olfactory scores (threshold, identification and composite scores) of both nostrils (values are mean ± SD)</th>
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<tbody>
<tr>
<td>Exposed group</td>
</tr>
<tr>
<td>Threshold score</td>
</tr>
<tr>
<td>Pre-work</td>
</tr>
<tr>
<td>Post-work</td>
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<tr>
<td>Loss score</td>
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<td>( P )-value(^c)</td>
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</tbody>
</table>

Loss score \( = ( \text{pre-work olfactory scores} ) – ( \text{post-work olfactory scores} ) \).

\(^a\)Standard deviation.

\(^b\)Student’s \( t \)-test: exposed group versus reference group.

\(^c\)Paired \( t \)-test: pre-work versus post-work.
non-smokers, but the difference was not statistically significant (t-test, P = 0.09 and P = 0.15 for both the exposed and reference groups). The decrease in composite score was highest in smokers in the exposed group followed by non-smokers in the exposed group, smokers in the reference group and non-smokers in the reference group.

A comparison of the results of the post-work olfactory function test between the ABS worker cohort as a whole and the reference group revealed significant olfactory impairment in the exposed workers (χ² test, P = 0.02). Based on the results of post-work olfactory function test, 4% of the ABS workers had moderate hyposmia, compared to none of the reference group subjects. Furthermore, 60% of the exposed workers had mild hyposmia compared with 40% of the reference group.

Moreover, only 37% of the exposed workers had normosmia (as presented in Figure 2). A comparison of the pre-work olfactory function test for the two groups did not reveal any statistical difference (χ² test, P = 0.70).

**Discussion**

This study tested the olfactory function of subjects pre- and post-work on a Thursday. We found similar olfactory scores and normosmia proportion in the reference group compared to past studies [13]. Data from this study revealed that the exposed group had significantly lower mean composite scores and larger decreases in composite score in both nostrils compared to the reference group after the workday. This phenomenon was interpreted as indicating that ABS plastic injection-moulding workers
may have weaker olfactory function than workers in other departments and the ABS plastic injection-moulding process may have a deleterious impact on worker olfactory function.

Several causes for olfactory aberration exist. First, catarrh can explain 30% of cases of olfactory aberration. Olfactory cleft inflammation is caused by nose inflammation, infection and irritation [16]. Secondly, upper respiratory tract infection (URTI) can explain 14–26% of cases of olfactory aberration. Thirdly, head trauma can explain 10–19% of cases of olfactory aberration. Other significant causes include aging, exposure to irritant gas, hereditary factors and congenital olfactory nerve defects [12].

Many raw plastic materials and TDP can cause occupational olfactory damage and irritation [8,17]. Several case reports already exist concerning styrene-induced asthma and rhinitis with occupational or environmental causes [18,19]. Unfortunately, the environmental exposure in the ABS plastic injection-moulding areas was not sampled and analyzed in this study. Thus it is impossible to speculate about the cause of the olfactory loss. Sensory irritants inhaled via the nose can have a range of effects on the nasal airways, besides eliciting chemosensory complaints. Irritants can increase blood vessel permeability, alter secretions from mucoserous glands, alter nasal mucus flow patterns, reduce the activity of cilia on respiratory epithelial cells (with adverse effects on mucociliary clearance) and suppress breathing rate [8].

Analyzing the threshold and identification scores of the composite score composing items separately, we found that the degree of decrease in the threshold score of the exposed group was greater than that of the identification score. This phenomenon implies that the effect on olfactory function of working in the ABS plastic injection-moulding areas is mainly decreased olfactory threshold score, not the identification score. This conclusion agreed with the olfactory function study of exposed cadmium workers [13].

The reductions in composite score after 1 workday followed the order ‘smokers in the exposed group’ > ‘non-smokers in the exposed group’ > ‘smokers in the reference group’ > ‘non-smokers in the reference group’. This pattern suggested that olfactory loss of the ABS plastic injection-moulding workers after 1 workday was greater than in the reference workers, even when the confounding effect of smoking is considered. Several studies have already examined the relationship between smoking and reduced olfactory function [17,20]. Data analysis from the post-work composite scores of the two groups showed that olfactory function difference between smokers and non-smokers in the ABS TDP exposed group was lower than that of the reference group, but this was not significant ($P = 0.09$ and $P = 0.15$, respectively; shown in Table 3). Based on the olfactory function distribution in the two groups (see Figure 2), the olfactory function of ABS plastic injection-moulding workers may decrease after one night of workday compared with the reference group. Fortunately, the results of the pre-work comparisons indicate that the decreases in olfactory function recover after one night of
rest. However, the cumulative effect of exposure to ABS TDP over the longer term is uncertain. The exposed workers in this study had an exposure history of only 7.3 years. It is proposed to follow the exposure effect and attempt to identify the cause of olfactory loss in future studies.

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References